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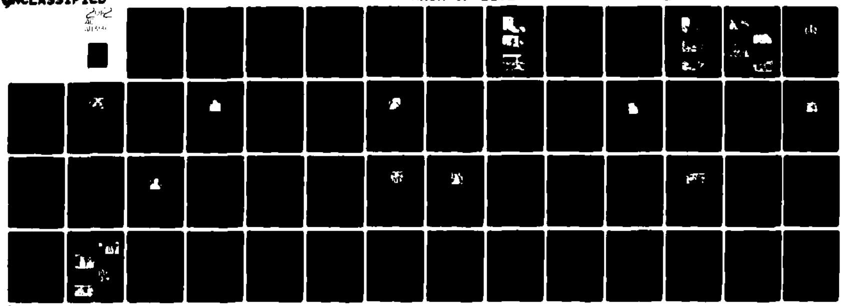

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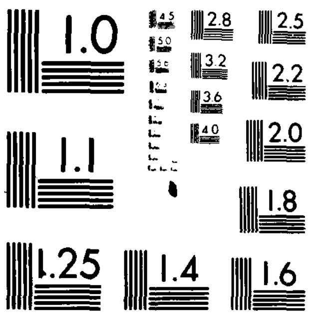


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

ATMOSPHERIC ELECTRICITY HAZARDS PROTECTION

Rudy C. Beavin

Wright Patterson AFB, OH

The Flight Dynamics Laboratory of the Air Force Wright Aeronautical Laboratories (WPAFB), Ohio, will administer an Advanced Development Program (ADP) with the Defense Nuclear Agency (DNA), FAA, NASA, the Air Force, Army, and Navy sponsorship directed at Atmospheric Electricity Hazards Protection (AEHP) for flight vehicles. The request for proposal is anticipated to be issued in June 1981 with contract initiation in September 1981.

The AEHP ADP will be conducted in two phases. The first will address the AEH threat as characterized by the USAF, NOAA, and NASA programs, as well as literature review and refined analyses followed by configuration of AEHP concepts for fixed wing aircraft, helicopters, and cruise missiles. The AEHP concepts developed will apply balanced system level protection approaches to counter induced threats to information flight/weapon control and propulsion/electrical power systems. In Phase II of the program, these concepts will be ground demonstrated in representative airframes using atmospheric electricity simulators.

THE JOINT AIRPORT WEATHER STUDIES PROJECT

John McCarthy

National Center for Atmospheric Research

Several people raised the question of what has come out of this workshop over the years. I've attended three, and the last two years have been pretty heavily involved with a discussion of wind shear. I left here last year with several recommendations in my mind that came from Bill Melvin's wind shear group and went back to NCAR to put together a program which I'd like to tell you about. It is called JAWS which stands for Joint Airport Weather Studies Project.

I'd like to show an example seen in Figure 1. The only really good example that we have of a microburst event was collected by Doppler radar. We're looking at a very small scale, very intense wind event that occurred near O'Hare Airport in 1978. This wind shear occurred near the final approach altitude and decision height altitude of a potential aircraft approach-to-landing. We're looking at a single Doppler analysis in which continuity considerations were applied to determine the vertical winds component; the horizontal velocity components are measured directly by the radar. There was a 62 knot wind max at an altitude something below 100 meters, probably at less than 50 meters altitude although it's hard to determine that precisely.

Notice the horizontal scale. This is three kilometers right here. This horizontal wind is on a very small spatial and temporal scale. Essentially this intense wind shear occurred below decision height on a scale well inside the final approach source and was in fact on the length scale of a typical major airport runway. The horizontal gradient of wind is tight. The vertical wind is also strong. The downdraft is around 12 meters per second up here at 3,000 ft but by the time you get down to the critical point of the approach, it is a very small vertical wind. This particular analysis is suggestive that coming up with very large vertical winds as a critical part of the downburst in the immediate approach and departure point of an aircraft just isn't correct. I think Ted Fujita, who is working with me very closely, is really very much in agreement that right on the deck the vertical winds just cannot be very strong, so it is the horizontal component that is really significant.

As you can see in Figure 2, the Joint Airport Weather Studies project, or JAWS, was developed about a year ago in concept and is much related to this workshop in a program that Ted Fujita,

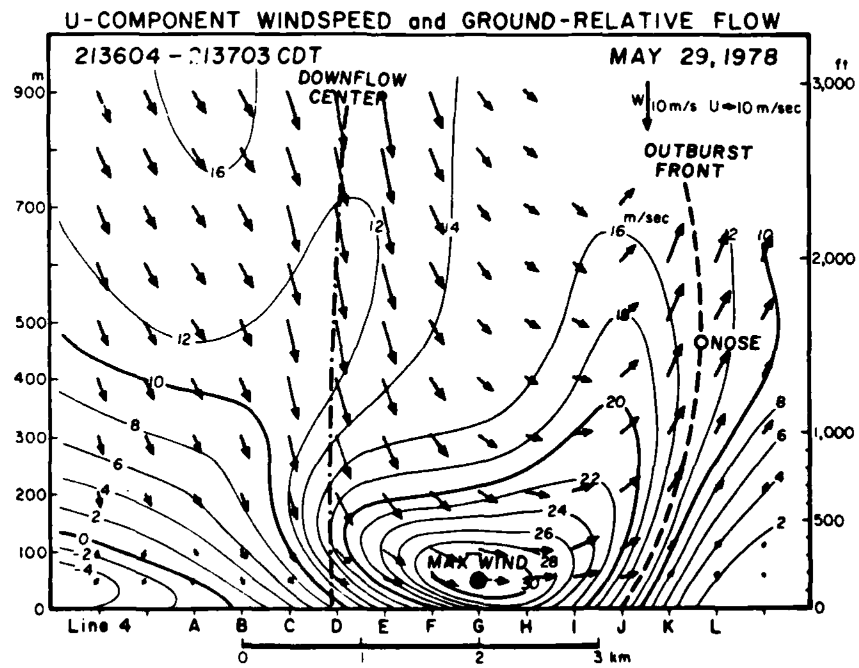


Figure 1. A vertical cross section through the 29 May 1978 microburst showing isotachs of horizontal windspeeds. The height of the maximum wind is estimated to be 50 m or lower. Arrows are ground-relative velocities in the plane which is stretched vertically.

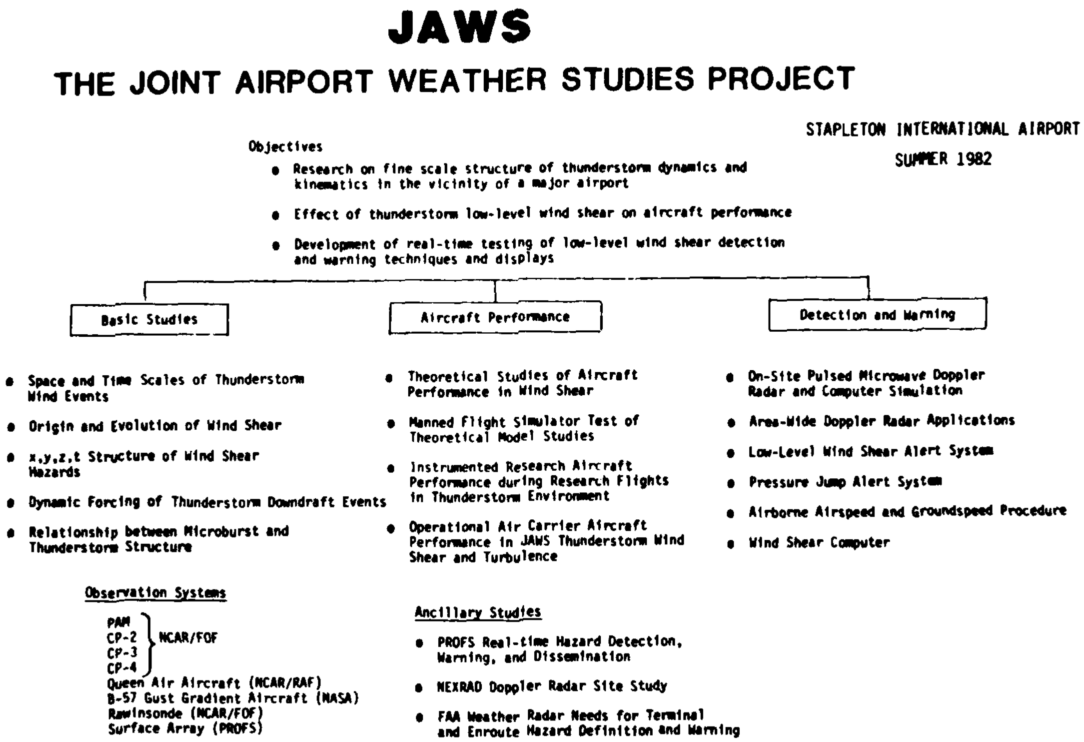


Figure 2. Block diagram of the JAWS Project.

myself, and another scientist at NCAR, Jim Wilson, have put together. It is a joint Chicago/NCAR project, and we've gone to several mission agencies as well as the National Science Foundation for funding. I can say that the prospects are really excellent now for this program to be funded.

The scientific background to the JAWS program is shown in Table 1. The thunderstorm microburst, the very strong low-level wind shear event like the one I just showed you, is poorly understood. Another way of saying it is as atmospheric scientists, we have missed the boat. In the past, we have not been looking at scales of motion that are one, two, three kilometers across the horizonal and for events that last only for a few minutes, like five minutes or ten minutes. There are a lot of reasons for that which I won't really go into except that we have tried to look at a larger scale in the thunderstorm and have filtered out the scale of motion that is on the scale that I'm talking about here. It was also believed in the earlier work that the gust front was a big deal. We don't believe that it is with respect to immediate approach and departures. We don't want to go through gust fronts, but we can do a pretty good job of avoiding them most of the time, and also they don't produce scales of motion that perhaps are critical to aircraft performance. We've been talking yesterday in our group that we need to examine what this scale of motion does in detail to aircraft performance. There are six low-level wind shear detection and warning systems that are either planned or implemented, and none have been tested adequately in my opinion with appropriate wind shear models or actual data. Some don't address the correct scale, and the JAWS program will be addressing this. Finally, with regard to the

TABLE 1

SCIENTIFIC BACKGROUND LEADING TO DEVELOPMENT OF THE JAWS PROJECT

- Thunderstorm microburst (10 to 30 km, 5 to 20 min) event poorly understood.
- Numerical and manned flight simulations indicate small scale or microburst event critical to aircraft performance in airport terminal environment.
- Six low-level wind shear detection and warning systems are implemented or planned--while each system provides important information, none has been tested adequately in a uniform environment containing a microburst event.
- Adequate observation, detection, warning, and timely dissemination of severe local weather hazard for public and aviation communities need major advances.

adequate observation, detection, and warning of events of this space scale and of this short liveliness, we're in terrible shape in that area. If you're talking about something that lives and dies inside of five minutes, our system has not been designed to get after it. To meet these scientific deficiencies, the JAWS project was created.

As shown in Table 2, the JAWS project will occur at Stapleton International Airport and vicinity in the summer of 1982. We have four areas of objectives. Basic studies in Table 3 are to define the kinematics, dynamics, and life cycle of thunderstorm wind shear events. We just don't have the data today to do this. The FAA wind shear program just didn't go after the right scale in our opinion, so this is an attempt to go back and collect the appropriate data. Why

TABLE 2

JAWS

THE JOINT AIRPORT WEATHER STUDIES PROJECT
Stapleton International Airport, Summer 1982

OBJECTIVES

- Research on fine scale structure of thunderstorm dynamics and kinematics in the vicinity of a major airport.
- Effect of thunderstorm low-level wind shear on aircraft performance.
- Development of real-time testing of low-level wind shear detection and warning techniques and displays.

TABLE 3

BASIC STUDIES

- Space and time scales of thunderstorm wind events
- Origin and evolution of wind shear
- x,y,z,t structure of wind shear hazards
- Dynamic forcing of thunderstrom downdraft events
- Relationship between microburst and thunderstorm structure

Denver? It probably has the highest thunderstorm frequency in the United States which may come as a surprise to some people. We have mountain forcing along the front range of Colorado, and there are a few believers I know in the crowd who have hung around Denver. We have somewhere between sixty-five and ninety-five thunderstorm days in a three month period in the summer which is higher than Florida, and although the frequency is extremely high, Denver storms typically are not tornadic; some tremendous wind shear type events do occur. JAWS will study aircraft performance as indicated in Table 4. We're going to be looking at further theoretical studies of aircraft performance with high resolution wind shear data in four dimensions; that is the x, y, and z and time distribution with very high resolution of wind shear events. We don't have the data now to do that. These data need to be studied, not only in the context of aircraft performance but for training needs in man flight simulators. We will probably have three instrumented research aircraft that will be collecting data and doing several other things. We hope to have a tie-in to the operational air carrier program at Denver, perhaps obtaining wide body digital data. These are areas that we are investigating:

TABLE 4

AIRCRAFT PERFORMANCE

- Theoretical studies of aircraft performance in wind shear
- Manned flight simulator test of theoretical model studies
- Instrumented research aircraft performance during research flights in thunderstorm environment
- Operational air carrier aircraft performance in JAWS thunderstorm wind shear and turbulence

Detection and warning (Table 5). On site pulsed microwave doppler radar looking up at the approach path and all possible three degree approach paths to the Denver Airport, using Walt's model we will be at least going through a game of using a numerical model with an approximate pilot in the model to compute aircraft performance along approach and departure paths in real-time. We will be using area-wide doppler radar to study wind shear and other small scale wind events in the Denver area in real-time. We will be evaluating the low-level wind shear alert anemometer system in the context of the thunderstorm environment. We will be looking at the Bedard pressure jump array in the Denver area. Finally, we will at some level be examining the airspeed and ground speed procedure in the con-

TABLE 5

DETECTION AND WARNING

- On site pulsed microwave doppler radar and computer simulation
- Area wide doppler radar applications
- Low-level wind shear alert system
- Pressure jump alert system
- Airborne airspeed and ground speed procedure
- Wind shear computer

TABLE 6

ANCILLARY STUDIES

- PROFS real-time hazard detection, warning, and dissemination
- NEXRAD doppler radar site study
- FAA weather radar needs for terminal and en route hazard definition and warning

text of a real thunderstorm wind shear environment. The point of this is to accomplish a thorough examination of all of the planned or available wind shear systems in a true thunderstorm environment. They will all be compared to one another in a rigorous manner.

A very important part of the program which I have here is called ancillary studies (Table 6). There will be an examination of one NOAA program which was not mentioned a few minutes ago, called the Prototype Regional Observing and Forecasting Service. This is a NOAA program where there is an attempt to do real-time detection, warning, and dissemination of Denver area weather in a futuristic weather service mode. It's a program that's within the NOAA Environmental Research Laboratories and NWS while FAA has a direct input to the program, particularly with Jack Hinkelman assigned to the program in Boulder. We will be operating a ten centimeter radar with the PROFS program which will be operated in a NEXRAD (Next Generation Doppler Radar) mode. We will be doing a number of things that relate to other objectives particularly in NEXRAD.

Observing Facilities. We will have the NCAR Portable Automated Mesonet, consisting of at least 27 stations for measuring wind, temperature, humidity, and precipitation in the area. We will have at least three doppler radars, the ten centimeter radar which will be operated in a NEXRAD manner, and two five centimeter radars located near the airport. We will have the NCAR Queen Air, the NCAR Sabreliner which is not shown and apparently the NASA B-57 Gust Gradient aircraft that Dennis Camp, Walter Frost, Jack Ehernberger, and several other people are involved in. We will have three rawinsonde units, and the PROFS Surface Array.

Figure 3 gives you some idea of the array. It's a little out of date because the position of the radar sensors. We will have one doppler radar on the field, and that will be the one that will be looking at radial winds along all approach and departure paths to the airport. We will have another doppler radar only 20 km away, and we will

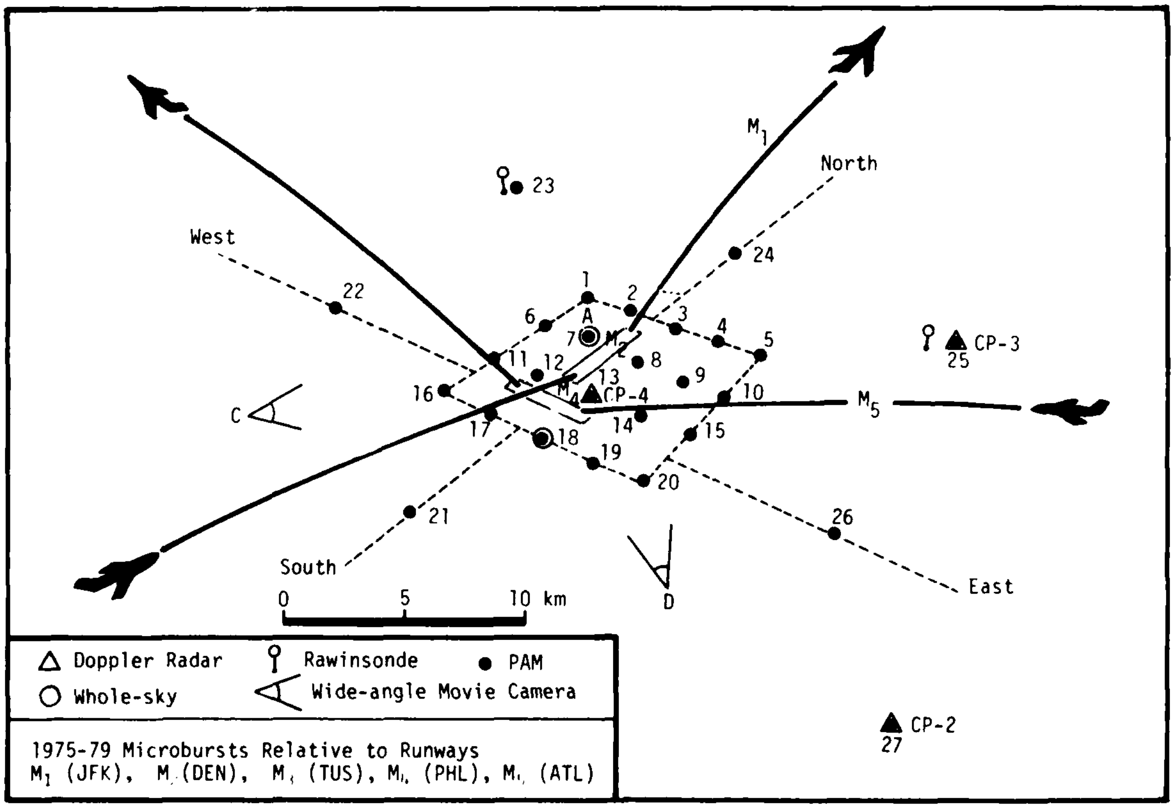


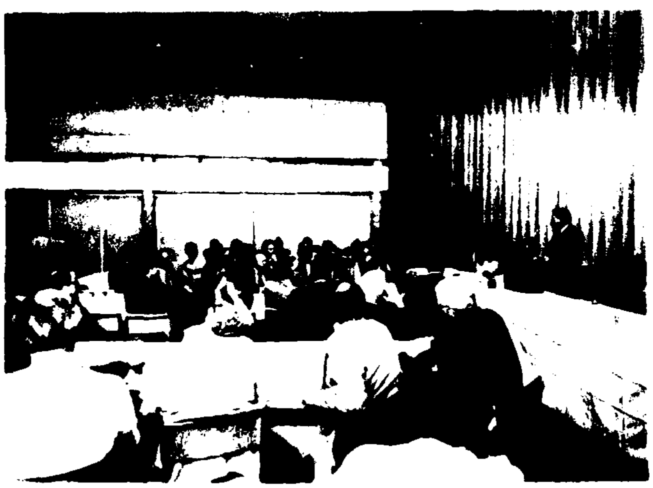
Figure 3. Illustration of JAWS Project observing facilities centered on Denver's Stapleton Airport.

be concentrating on looking at low-level wind in the clear air as well as in storms in the immediate airport area. Further to the north, we will have the ten centimeter doppler radar which will be operated in a multiple doppler mode when there is some interesting weather in this area and in a surveilance NEXRAD mode the rest of the time, operating the PROFS. There is also a significant chance that we will have two NOAA x-band doppler radars to increase our small scale array in this area.

That gives you a quick overview of the program. Many of these objectives have come right smack dab from this workshop, and I've given you only a quick look at it. I can talk to you in great detail about it. On an individual basis, many people here are involved with JAWS: Bob Roche is our FAA monitor while Dick Tobiason and Dennis Camp are our NASA contracts; certainly, Walter Frost will be working with us in certain specific areas. There are a number of other scientists involved such as theoretical atmospheric scientists, Bill Cotton from Colorado State University, Kerry Emanual from MIT.

JAWS is a 2.3 million dollar program. It begins in FY82, next October, and it runs for three years with the first year a field program, followed by two years of analysis and reporting. The other critical thing that is important is that the National Science Foundation which operates NCAR will be picking up half the tab of the program while we are asking the mission agencies to fund the other half of the program. Amost needless to say, we are very excited about the JAWS Project.

SECTION VI
DINNER PRESENTATION



METEOROLOGICAL IMPACT ON CORPORATE AIRCRAFT OPERATING COSTS

Richard Van Gemert

Xerox Corporation

Ladies and gentlemen, I consider it a distinct privilege to be afforded the opportunity to speak with you this evening. When asked to develop a subject for presentation, my first reaction was to draw a blank. Upon further consideration, a common thread began to develop. It became clear that where your various disciplines most hit my business was in my method of keeping score - dollars.

I would prefer this evening to develop a scenario of where corporate aviation is today, where it is going, the forces driving it, and some of the operational shortcomings to address over the next ten years. Particularly as these issues affect costs. You may consider it unholy not to list safety as my primary issue. I would hope that you would realize that we are sophisticated enough to know that without the desired levels of safety we are not in business. Therefore, safety is the underlying foundation of corporate aviation. It also must be accepted that there is an identifiable cost as well as savings to safety.

The latest data on general aviation usage published by the FAA is for 1978. I will primarily talk to the category of general aviation termed "Executive Aviation" which by definition is: any use of an aircraft by a corporation, company, or other organization for the purpose of transporting its employees and/or property, but not for compensation of hire, and employing professional flight personnel for the operation of the aircraft. I will further limit this discussion to turboprop and turbojet aircraft operated within the executive category.

In 1978 there were 1,971 executive jets operating in the U. S., flying a total of 899,000 hours. There were also 2,195 turboprops flying 885,000 hours in executive service. The four year growth trend showed an increase of 91.5 percent in turboprop aircraft and 73.8 percent in turbojet aircraft. The five year annual compound growth rate for aircraft in the executive category is 13.4 percent for jets and 4 percent for turboprops. It is important to realize that this growth in executive aircraft occurred during a decade of regulated air carrier operations. I believe it is fair to state that executive operations are not organized to compete with the scheduled air carrier. Executive operations are developed to complement those transportation shortfalls in the scheduled carrier environment. In areas where there is a specific transportation requirement not provided for by the air carrier in a cost effective manner, is where a private transportation system flourishes.

By way of background all of this verbage is fine; however, you may ask where does the weather come in? Today's executive operator is impacted primarily in four major areas by the availability or lack thereof of sound meteorological data:

1. Long range route planning
2. Dispatch ability
3. Enroute economics
4. Destination planning

The aircraft that we will operate in the 1980's all have significantly different operating characteristics than the aircraft we have been operating the past twenty years. These new aircraft include the Canadair Challenger, Cessna Citation III, Falcon 50, Gulfstream III, and Learjet 55. These aircraft are characterized by high bypass ratio engines performance, matched to supercritical wings. These aircraft will routinely operate at altitudes in the range of 39,000 ft to 51,000 ft. Here, it is also important to note the adverse impact of temperature on thrust deterioration with the high bypass ratio fan engines.

The core of all executive aircraft flight planning today is the computerized flight planning systems developed by Lockheed jetplan and some of the various airlines. These systems get all of their primary weather from the Suitland tapes provided by the National Weather Service. I will cover the existing shortcomings with the current tape inputs during my coverage of the enroute issues.

Unlike the scheduled airlines who can only operate in the world's airspace under existing international agreements, today's 'far ranging' executive operator exudes all of the entrepreneurial characteristics of their forerunners, the Clipper ship captains. As an example, in the past several years we have operated from Jeddah to Tokyo, Moscow to Cuzco, Peru and such garden spots as Leguna Del Sauce, Uruguay and Bodo, Norway. The shortcomings in all of these operations is reliable weather. Range is always an ingredient but route planning is imperative. Here we run into our first and one of our foremost problems. There is no forecasted weather in the computer data bases above flight level 390. As most of our new aircraft operate above flight level 390, temperature and wind above FL 390 show as a constant. It is an absolute must to get this data forecast to FL 430 and preferably to FL 470.

Another issue is to determine the weather at your destination point! Destination weather characterizes destination reliability. It is important to have forecast information that considers the impact of local phenomena. Since most terminal forecasts are computer generated, we no longer have this valuable analysis of local phenomena available. For this reason, private operators are subscribing to a private weather service specializing on such issues: such as universal weather service or national weather service. To operate outside the U. S. it is absolutely imperative to subscribe to

these services. Here, the forecast data can be transmitted to the crews hotel or dispatch agent. These data are not generally available locally in a language clearly understood by the crew.

Consider the effect of this type of knowledge statistically on the operation of our shuttle. We operate two and one half round trips per day between Rochester and White Plains. In the past twelve months, 1,162 flights were conducted by the shuttle. Four flights or in essense 9 percent were cancelled for weather and fifteen flights or 1 percent were delayed for weather. Weather delays totaled 11.7 hours or 1 percent of the total hours flown. It is interesting to note that if we use the airline criteria for on-time performance, this one aircraft carried 13,774 passengers with a 97 percent on-time performance record.

OPERATIONS ANALYSIS SUMMARY

As you can see, no longer can the U. S. businessman arrive at his destination in an unreliable manner. Deregulation will provide a continued growth emphasis to executive aviation as it becomes more and more difficult to connect our new plant sites in the sun belt with the established traditional business centers, as well as our foreign operations. Many of us have remote flight operations in foreign countries. We need your help to develop more reliable high altitude planning data, better terminal data, and better means of dealing with international weather. We are squeezing every nickel in our drives for efficiency. We are faced with performance opportunities that we have never had before as we look to our equipment changes in the 80's. We look to you folks to assist us in developing the operating weather data bases to assist us in achieving our goals. To you, I offer the challenge.

SECTION VII
COMMITTEE
SUMMARY REPORTS

SUMMARY REPORT: METEOROLOGY IMPACT ON AVIATION OPERATION EFFICIENCY COMMITTEE

Members: Andy D. Yates, Jr., Chairman; ALPA

Raoul Castro, Flight Safety Foundation, Inc.

J. Charles Derrick, Jr., Federal Express Corp.

Joe R. Kelley, Global Weather Dynamics, Inc.

Solomon Weiss, Consulting Engineer

Introduction

A review of recommendations from previous workshops indicated that most of this committee's recommendations are duplicates of those in the past. In spite of this, it is felt that the recommendations should be restated. The reason is that not enough finite information regarding specific programs designed to deal with prior recommendations were available to the committee. This years committee recommendations are briefly stated relative to the different subjects of discussion with the respective meteorological or floating committees

Discussion

The first subject is winds. More frequent updating of the winds aloft forecast and greater accuracy in forecasting are needed. The data base should be increased by asking airlines to furnish pilot reports to the NWS. The INS reports can be transmitted by the pilot through ARINC or by a data link. Development of an on-board system to detect wind induced turbulence and improved accuracy in forecasting turbulence is required. More frequent reporting of wind shift in terminal areas is another recommended action. Also, the committee recommends that Robert Steinberg's report, "Airline Flight Planning - The Weather Connection" (NASA/Lewis Research Center, Cleveland, Ohio) be considered and implementations of some of the recommendations within that report relative to flight planning specifically where winds are involved be seriously pursued.

Under icing and frost, the committee felt that number one priority be given to greater accuracy in forecasting icing conditions and also the frequency of forecasts be increased. The development of liquid water content (LWC) devices for on-board use in order to determine icing probability and accretion rate along with development of icing accretion indicators particularly for the general aviation type of aircraft is needed. Icing is not that much of a problem among the large commercial jet airliners but continued research towards better deicing and anti-icing equipment on-board general aviation aircraft is required.

Methods of deicing aircraft on the ground other than water glycol mixture or other petroleum products should be researched. This, of course, also directly attacks the heart of some of our fuel problems, glycol being a petroleum based product. The fact that it costs approximately $4 a gallon now, and will probably be as high as $5 a gallon within the next five years.

The committee also discussed whether this clearly shows the importance of cost effective deicing procedures. Putting airplanes in the hangar and warming them up rather than deicing is a viable option. No conclusion was reached.

Under lightning, the use of on-board detectors for the purpose of lightning avoidance is recommended. Research into the correlation between radar presentations and storm scopes under actual conditions is recommended.

Under fog, the committee recommends greater accuracy and frequency in forecasting. They noted that reporting the dissipation of fog as well as its formation is important. Secondly, examination of maintenance and reporting procedures for ground based visibility instrumentation should be re-evaluated.

Discussions with the ozone and other meteorological conditions committee was broken into three different subjects: ozone, acid rain/corrosion, and heavy rain. The committee's number one recommendation is funding and installation of

ozone sensors aboard selected airlines. Number two is to increase the ozone data base by data link with aircraft to a central repository. Number three, greater accuracy in forecasting and reporting ozone. Number four is consideration of rule making specifically aimed at cargo aircraft with regards to ozone concentrations.

The committee believes that the meteorological aspects of corrosion to aircraft from acid rain be investigated.

The committee concluded that interfacing operational efficiency with each of the various meteorological disciplines with which they conferred narrowed to four basic areas, greater accuracy in forecasting, greater accuracy in reporting, increased data base, and more frequent and timely dissemination of forecast reports and data.

Question and Answer Discussion

Question: (Unidentified) Why did you mention cargo aircraft relative to ozone?

Andy Yates: Cargo aircraft need to be looked at in view of the fact that the FAA rule making is designed for cabin concentrations. The committee felt that the FAA could probably come out with a rule stating it is not necessary to monitor cabin concentrations as much as it is to consider the effects on the crew. If the crew are the only persons aboard the aircraft, they could, for example, cope with the problem by donning oxygen masks or something of this nature. Note, this was purely a suggestion to research the possibility of rule making designed specifically for cargo aircraft, and of course, you have to look at it in terms of aircraft size. For example, obviously a Flying Tiger 747 will probably have different considerations than a Falcon Jet such as Federal Express.

SUMMARY REPORT: METEOROLOGY INPUT TO ADVANCED SIMULATORS COMMITTEE

Members: Carl Terry, Chairman; United Airlines

Gordon O. Handberg, McDonnell Douglas Electronics Co.

John T. Klehr, Link Division-Singer Corp.

Robert E. Smith, NASA/MSFC

Barry S. Turkel, FWG Associates, Inc.

Introduction

Our primary recommendation is simply that we in the simulation business and you in the research business become better acquainted. We must become more aware of the research results already obtained and their usefulness in our simulation systems while you must keep in mind that at some time in the near future we may have to build a real-time simulation of the phenomena which you are investigating. This will require for training simluators reasonably simple models capable of being executed in a digital simulation system already near capacity with a complete description of the aircraft crew's operating environment.

Within the context, commercial flight simulators are currently moving into improved simulation of the following phenomena:

1. Turbulence
2. Wind Shear
3. Low Friction Runways
4. Icing
5. Atmospheric Electricity and Lightning
6. Heavy Rain

Turbulence

Current advanced simulation systems are employing turbulence models based on either the Dryden or Von Karmen models. These models, however, need an added dimension, referred to by pilots as "patchyness". We need rational definitions of the short-term variations in intensity and scale length (or another variable) which will result in a more realistic representation of turbulence as it occurs in the real world.

A bit off the track of this gathering, but nevertheless important to our task, is the representation to pilots of the level of turbulence via flight simulator motion systems. We would like to see some investigation of the subjective evaluation of turbulence "feel" as a function of motion drive algorithms such as the NASA Coordinated Adaptive Filter System.

A third area of investigation within turbulence (and wind shear) is that of the effects of unequal wind components acting across the finite dimensions of the airframe. Are the current models involving pseudo angular rate filters or lagged tail angle of attack changes sufficient? Are there, in fact, better models in existence now but unknown to us?

Wind Shear

Some questions were raised concerning the validity of currently available wind shear profile models. Since the FAA commercial simulator regulations now require inclusion of "real world" wind shear profiles in advanced simulators, we recommend that the FAA Simulator Certification Division monitor the work to be done in conjunction with the JAWS project and with the current research into the effects of heavy rain on aircraft performance.

We also recommend continuation of the investigation into the effects of heavy rain, and should this prove to be a significant item, establishment of empirical models for predicting the force and moment effects on any airframe.

Low Friction Runways

Although this was not a primary item of discussion at this year's workshop, it is an area receiving a great deal of attention in advanced simulation. We require representative longitudinal and lateral tire friction coefficient data for operation on wet, slushy, icy, and snow-covered runways. Additionally, since we must

simulate "mixed" conditions (wet with icy patches, slush patches, etc.), we must have models to simulate the transient effects of anti-skid systems.

Icing

Receiving less attention at the moment, but still included in simulation requirements are the effects of airframe and engine ice. We are in need of models for simulating the rate of accumulation and type of ice occurring as a function of atmospheric conditions and flight regime.

Given those models, we then need empirical models of the effects of airframe and nacelle (or propeller) icing upon the aerodynamic coefficients and engine parameters. Results of the current investigation into helicopter rotor icing should be brought to the attention of the manufacturers and users of helicopter simulators.

Atmospheric Electricity and Lightning

With the advent of large scale digital avionics usage, e.g., Boing 757 and 767, simulation of the adverse effects of lightning strikes may be required. This simulation would not only require data concerning computer failure modes, but for realism, data relative to the effects of charge buildup and lightning strike upon communication and power generation systems.

Heavy Rain

Within the current training simulators environment, no new research seems to be required to aid in visual simulation of fog and rain. It would appear that any contemplated improvements in these areas could be developed with reference to existing information.

Throughout many of our meetings, we found ourselves discussing operational procedures rather than simulation techniques. Since operational procedures dictate what must be included in a training simulation, this is not too surprising. It does, however, point out the fact that disagreement exists concerning not only how one is to simulate certain phenomena, but as to what is to be simulated in the first place. As an example, the question was raised as to whether wind shear simulation has a place in a training simulator at all since it would not seem wise to teach pilots to fly through wind shears as opposed to simply avoiding them. However, should cockpit wind shear detection systems be employed, it would then be mandatory to train pilots in their usage in flight simulators, and valid shear profiles would be required.

The possible use of an advanced flight simulation system for investigations into exactly what types and levels of wind shear are dangerous to operations was also discussed. This information would be used to calibrate a "go/no go" decision level to be used in conjunction with a real-time wind shear measurement system.

Our discussions with Jim Luers concerning heavy rain effects also had operational procedures overtones in that some recommended wind shear recovery techniques could actually result in greater risk and worse performance in heavy rain.

We, on the Advanced Simulation Committee, have found this to be a very informative and interesting workshop. Each of our meetings seemed to pass far too rapidly often only allowing us to get "warmed up" to the subject at hand. We do feel that a meeting with the Operations Fixed Committee would have been useful, perhaps even a three-cornered meeting among the Simulator Committee, Operations Committee, and a group composed of training people. Such a meeting would allow us to discuss available technology as it applies to operational and training policy.

I would like to thank Dr. Frost and the Organization Committee for inviting each of us here, and to wish them continued success in the future.

Question and Answer Discussion

Joe Stickle, LaRC: Just one comment. I think you eluded to the use of the TCV simulator at Langley for turbulence research. That is a fixed base simulator.

Question and Answer Discussion

Raoul Castro, Flight Safety Foundation: We have had some accidents in the last couple of years indicating that the training in the simulators hasn't been carried to the actual cockpit of the airplane. Do you have any idea what could be done to improve the transference of the training in the simulator to the cockpit?

Carl Terry, United Air Lines: This is an area of an extremely large amount of investigation and discussion. I think that I am a little too varied into the technical end of the thing to have an unbiased opinion. I have my ideas, but they are mainly that. I'd have to refer you to the literature.

SUMMARY REPORT: OPERATIONAL PROCEDURES RELATIVE TO SEVERE WEATHER COMMITTEE

Members: Fernando Caracena, Chairman; NOAA

Rick Clarke, Flight Safety Foundation, Inc.

Kirk Lehneis, Scott AFB

William W. Melvin, ALPA

Gregory D. Salottolo, NTSB

James F. Sullivan, USAir

C. Dennis Wright, AOPA

Introduction

The committee's discussions ranged over the following list of topics: (1) wind shear, (2) radars, (3) data link systems, (4) flight training, (5) fog dispersal, (6) atmospheric electricity, and (7) general aviations' problem of accessing good weather information.

Wind Shear

There was a great deal of interest in the topic of wind shear; how a pilot should manage it; what is the proper pilot training procedure, the need for a good terminology, and the role of heavy rain in wind shear accidents.

The committee recommends that in a wind shear encounter a pilot should use the optimal performance configuration for his aircraft; and not try to fly aircraft out on the "stick-shaker" as has been suggested in the past. The attempt to maintain altitude in the face of rapidly deteriorating airspeed is a dangerous procedure that could end in disaster.

Perhaps the "stick-shaker" procedure has evolved from a misinterpretation of the character of thunderstorm wind shear. The aircraft industry first recognized the wind shear hazard in an accident involving a frontal type shear. Across a frontal inversion, winds that are almost horizontally homogeneous change rapidly with height. An aircraft descending or ascending through the frontal inversion experiences rapid changes in the airspeed. Its rate of encounter with the wind shear is proportional to its vertical velocity. If the aircraft's rate of descent or ascent is arrested, then the effects of the shear disappear. Flight simulators containing this type of shear give a clear but misleading message: arrest the rate of descent or ascent of the aircraft and the effects of the wind shear disappears. Unfortunately, in a thunderstorm situation that doesn't happen because of strong horizontal wind shear components.

In a thunderstorm the winds are far from being horizontally homogeneous. Downdrafts produce strongly diverging surface winds. As an aircraft flies across the base of a strong downdraft, a strong headwind may rapidly switch around to become a strong tailwind. In this case the rate of encounter with the windshear is proportional to an aircraft's horizontal motion, and arresting an aircraft's rate of descent is not going to alleviate the rapid loss in air speed. Only a complete stopping of the aircraft's horizontal motion will arrest the aircraft's encounter with this type of shear. Therefore, the "stick-shaker" procedure that might be applicable to encounters with frontal type shear is inappropriate and dangerous in a thunderstorm wind shear encounter.

Wind shear training programs and terminology

A deficiency in wind shear training programs came to the attention of the committee. Some flight simulator profiles are deliberately designed so that it is just barely possible to successfully penetrate the wind shear. This tends to create the false impression on trainees that any wind shear can be penetrated by using the correct techniques. Past research shows that there are some wind shears so severe that no commercial aircraft is going to be able to successfully penetrate them. In this case, the best procedure is one that results in the softest impact. The upcoming JAWS project may shed additional light on the degrees of wind shear severity that are likely in downbursts and microbursts.

The committee discussed the need to develop a

clear non-technical presentation of wird shear for pilot training. Along with this, there is a clear need to develop an ICAO standard terminology for describing the effects of wind shear on flight performance. At present, aeronautical engineer, meteorologists, and pilots have different terminologies for wind shear which is an additional source of confusion.

Wind shear and heavy rains

More research needs to be done on the effect of heavy rain on flight performance. There is no doubt that heavy rain or high liquid water content in the atmosphere will degrade the flight performance of an aircraft. Current research on the subject, however, does not give a good estimate of how large the effect may have been in a number of recent accidents that have been attributed to wind shear. Certainly, research results at the present do not justify headlines to the effect that heavy rain and not wind shear may have been the actual cause of these accidents.

Let us remember that there were direct indications of strong wind shears during several of the accidents in question. At J. F. Kennedy International Airport, a number of aircraft were affected by strong cross winds as well as headwinds and tailwinds before the crash of Eastern Flight 66. Heavy rain which may simulate changes in the headwind component cannot simulate strong cross winds. Also the presence of strong cross winds implies strong longitudinal components of wind as well since these winds were driven by thunderstorm downdrafts. At Philadelphia International Airport, the aircraft attempting to land ahead of Allegheny Flight 121 encountered such strong headwinds that the pilot could not force the aircraft down to the end of the runway and for this reason elected to go-around. Eyewitnesses at the surface reported strong winds as well as heavy rain. When Allegheny Flight 121 was on the approach, the cell that had caused the strong headwinds previously had now moved to the edge of the runway. After flying under this cell, the aircraft crashed because the strong headwinds that it was experiencing suddenly disappeared. Thus, in both Eastern 66 and Allegheny 121 accidents, there were strong wind shears as well as heavy rain. We know that the wind shears were strong enough to cause other aircraft problems even when these aircraft were not directly affected by heavy rain.

A detailed investigation of wind shear accidents shows that there have been wind shears strong enough to crash airplanes without any help from heavy rains. At Denver, Continental Flight 426 was downed by a thunderstorm that produced only very light rain. At Tucson, a dry thunderstorm produced strong winds, blowing dust, and only a light sprinkle, and yet in each case the wind shear generated was strong enough to cause an accident.

The importance of heavy rain is not that it may be the "only real villain" in wind shear accidents, but that it produces an effect in the same direction as that of the wind shear. Heavy rain is likely to be found in association with a strong downdraft. Its presence worsens the performance of the aircraft, and the combined effect of heavy rain and wind shear may be to make it virtually impossible for an aircraft to survive the encounter.

X-Band Vs. C-Band radars

The committee discussed the problems associated with present airborne radars. Most commerical aircraft use X-band radars. It is known that X-band radars have severe attenuation problems that tend to distort the radar presentation of severe thunderstorms. This can lead a pilot to be dangerously mislead about the structure of a storm that he may be trying to navigate around. This problem can be alleviated to some extent by having commercial airlines switch to the use of C-band radars. At present one of the major airlines uses the C-band radars. In general, the longer the radar wavelength, the less is the problem of attenuation; however, size requirements for the radar antenna limits the practical range of wavelengths for airborne radars in commercial aircraft. Incidently, pilots should be made aware of radar attenuation due to wet radomes. Attenuation due to a wet radome results in a deceptively weak radar return. This is true of both C-band and X-band radars.

While the use of a 10 cm radar such as is available from a WSR-57 would be very valuable to the pilot, it would be far from practical to mount one in an airliner. However, the radar presentation of a ground based WSR-57 could be made available to the cockpit by means of a data link system.

Data Link System

As in past sessions, our committee recommends the implementation of a data link system. The ACAR data link system now being planned could become a means for gathering meteorological data from aircraft in flight. After processing on a central computer, this data could become the basis for continually upgrading forecasts which in turn could be uplinked back to aircraft in flight. In addition, other meteorological data such as WSR-57 radar scope presentations could also be relayed to the cockpit to augment the aircrafts own radar. The use of a larger area radar presentation with minimum attenuation would be an important supplement to aircraft's own radar.

Icing, Fog Dispersal, and Ozone

Many old skills that were learned in the past in flying through severe weather have been for the most part forgotten. Now with increased operation of commuter and air taxies at low altitudes in severe and inclement weather, there is a need to revive these skills. For example, the air man's information manual should have a note about possible loss of control of some aircraft due to tail plane icing when the flaps are lowered. Control is restored by raising the flaps.

There is a need to do a thorough study of the

cloud physics during various icing conditions to define quantitative degrees of icing which include icing due to freezing rain. There is a need for continued research on fog dispersal, further study on ozone, its distribution and its effects on people.

Recent government regulations now require commercial airlines to maintain less than a certain concentration of ozone in the passenger compartment. We need to know more about physiological effects of ozone on people, and how long can they be comfortably subjected to a variety of concentrations of ozones. There is a need to be able to predict the likely concentrations of ozone to be encountered in a variety of flight paths. Perhaps present airline regulations concerning ozone are too stringent. In an attempt to meet these standards many commercial airlines are flying at too low altitudes resulting in a heavier consumption of fuel at a time that we are also trying to conserve energy. Research on the ozone problem should continue toward defining this problem more precisely and toward arriving at reasonable standards.

Atmospheric Electricity

The committee discussed the increasing aircraft hazard due to atmospheric electricity as aircraft design moves away from all metal aircraft bodies in favor of composite materials. Microprocessors are particularly susceptible to damage from weak electric discharges. The other tendency in aircraft design toward the use of "smart" control components and to wire controls make future aircraft particularly susceptible to lightning strikes. For these reasons, the committee urges that research be continued on the effects of lightning strikes on aircraft and on the possible use of fiber optics for control circuits within the aircraft. The development of the storm scope should also be continued. Perhaps the storm scope presentation can be overlayed on the radar display.

Problems in accessing weather data

The committee discussed the need for better weather data. One of the deficiences in our present system is in the lack of weather data from remote airports. The solution to the problem is to use automatic reporting stations at these remote sites which would be particularly useful in mountainous areas. This problem is of particular concern to general aviation which also has the additional problem of tapping existing weather information.

The weather-related accident rate in general aviation is very high, perhaps because general aviation has a much more limited access to weather data and quality, up-to-the minute forecasts than do commercial and corporate airlines. The solution to this problem will have to be supplied by people in general aviation themselves. Collectively they have considerable financial resources which they could use to purchase high quality and timely weather information.

One last recommendation of the committee is that an inconsistency be cleared up to insure the compatibility of the FARS regarding operations in icing conditions and the present definition of severe icing.

Question and Answer Discussion

John Prodan, AV-CON: I take strong issue with the next to the last one that you have that general aviation has a responsibility to go out and get better weather information. It seems to me that NWS, NOAA in particular have the information and the problem of dissemination to general aviation pilots. It is not the responsibility of general aviation people to go out and hire a private consultant when we're paying for it on April 15th to have it available. It's a problem of dissemination of that information to the aviation public, and I really believe that the first responsibility is with NWS.

Fernando Caracena, NOAA: My remark was directed to the fact that for the next few years it looks like it's going to be very hard to get anything extra out of the government. The NWS is reducing the number of personnel and cutting back services, so it's really a political problem, and I don't see a solution to it within the next few years unless general aviation acts on its own initiative. However, I agree with you; the timely dissemination of weather information to the general public is the responsibility of NWS.

SUMMARY REPORT: METEOROLOGY IMPACT ON FUTURE AIRCRAFT DESIGN COMMITTEE

Members: Richard L. Foss, Chairman; Lockheed, California Company

Ronald R. Brown, Wright Patterson AFB

John C. Houbolt, NASA/LaRc

Gary S. Livack, GAMA

Dennis Newton, LearFan Corporation

Introduction

The first thing that I'd like to say is that I'm delighted to have been invited to this workshop. I'm a first timer, and I'm really impressed. When you get together with a bunch of guys that work in meteorology, they go all out. You could not have planned better weather, but I want to warn you that if we had weather like this all the time, you would be out of a job. So, be careful!

As you who participated in our meetings know, our group invented a diagram to help us sort out what it was we were trying to get from you. It's a flow chart that indicates what it is we're after (Figure 1). To enter the diagram, you presume that there is a problem, be it ice, snow, whatever.

Discussion

The first question we asked was--can we characterize this problem from a meteorological standpoint? There is either a yes or no answer. If the answer is no, you in meteorology have the ball. It means that we still don't understand the basic problem. We make a note of it, and we say you should do some more work, and we'll be back at you later.

If the answer is yes, then we drop down and ask a second question--namely, can we operate the airplane so that we can avoid the phenomena? In some cases, perhaps thunderstorms and the sport or general aviation pilot, we're off the hook because he can avoid the problem.

However, in many cases the answer is no. It cannot be avoided, so we have to drop down to question number three, and as designers ask the question--what can we do with existing technology so that we can cope with this weather problem? We get in the loop, and we're asking questions of ourselves and asking for help. What can we all do designwise to solve the problem? In many of our discussions, we found ourselves making forward projections that led us to composite materials and/or digital controls.

We don't understand many aspects of these technologies as they relate to weather problems, and therefore, cannot say positively that we know how to cope with a weather problem using technology. We have to do some research and development and then come back again with new technology and ask that question a second time. We continue that iteration until we get a yes answer--yes, we know how to solve the problem; then we can drop down to the next question.

The last query relates to regulations, specifications, and standards. Are all of that data updated, current, and useful? Or do we have to educate, modify, and update? As each panel of experts joined us, we asked you these questions. These are the questions--what I'm going to do now is tell you what we have in the way of answers.

We'll start with lightning. We feel, yes, you can characterize the phenomenon of lightning, but probably more research is highly desirable. We don't think we know all there is to know, so we endorse the idea that we go out and get more data.

Can we avoid lightning? I think the real answer there is no. We must at least go in the vicinity of thunderstorms, and when we do that, there is always the likelihood of a strike. Therefore, we as designers have to consider the consequences of an airplane being struck by lightning. Is the technology ready? With regard to metallic airplanes with conventional control systems, as

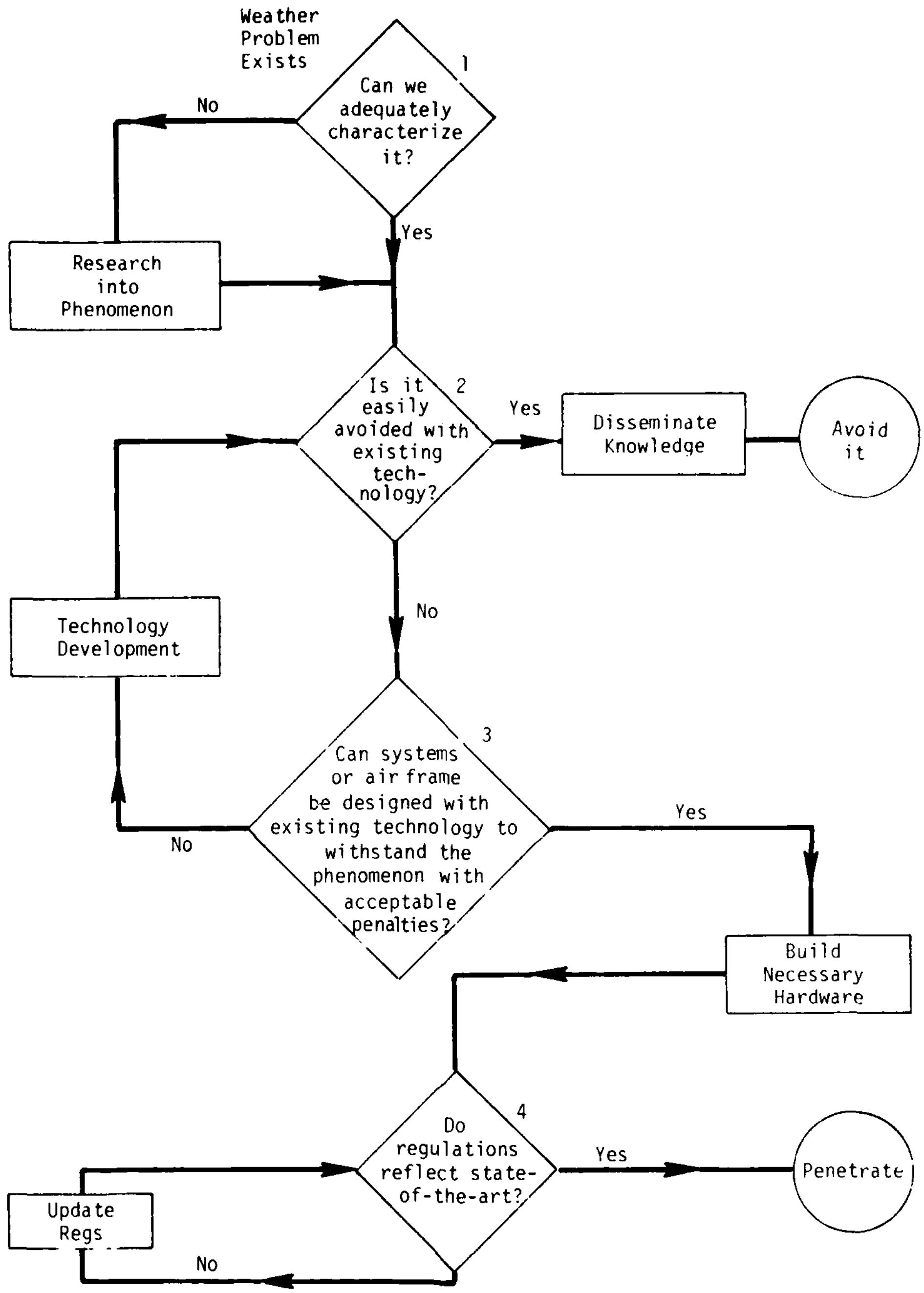


Figure 1. Flow chart diagram.

we're familiar with today, the answer is yes. However, as we go into these newer non-metallic materials, then the issue of protection becomes less definitive. Some companies are doing a lot of work in non-metallic materials and are pursuing the problem of lightning protection and feel that they have the answers. Other members of industry who are not yet involved in non-metallics probably feel that they don't know all the answers. We are in the middle on that one.

I think everybody on our panel agreed that when we go further and further with digital controls, especially if combined with composites. We're less and less confident, more and more on the no side, suggesting we need to do more work. We encourage those in the research area who are looking at lightning and protection to press on. We need more information. With regard to regulations and design specifications today, they are probably definitive, but in the future the answer will be that they are not and will have to be updated.

Second subject, second problem--for or reduced ceilings and visibility. Here again, we think from the design standpoint that you the meteorologist can define and characterize the information we need.

We cannot avoid it. We must design for it. In the commercial area, we're working the problem. We have the tools with digital advancements and new displays. We think we're going to resolve the problem. Unfortunately though, when we get into business aircraft and in particular, commuter aircraft, the systems we can see are not affordable. Therefore, we do not see an immediate yes answer for technology in commuter or the small airplanes. Research will not drive the cost down. I think we have to see this technology introduced in the larger commercial transports first, and then with more and more production, unit costs will go down and make it more affordable for the smaller aircraft.

Third problem area--ozone. Can we characterize it? We feel you can, yes. Can we avoid it? Yes most of the time. It's probably something we can schedule, either with altitude or perhaps by route direction. Commercially we can at most times anyway avoid the ozone problem.

For some operators, avoidance is impossible because of polar routes, high altitude routes, and long range routes. Therefore, catalytic filter systems are going into their aircraft. They cost a little money, and they cost a little weight, but they're considered desirable and are going into service.

There are regulations in process. Ozone is one area where we think that we are pretty much on top of the problem.

We had some discussions regarding acid rain. At the present time, we don't think this is a problem; however, we mention it and think it should be monitored in future workshop sessions. It's one of those things that could drop in a crack. The biggest concern related to acid rain is corrosion. We should monitor its effects to see if the problem gets serious. It may be that it gets serious only in local geographic areas, and there are ways to operate around it. As we go into advanced light weight materials (nonmetallic materials), do we have to have more protection, paint, or whatever? These are the concerns that may surface. It is a good item for this group to keep in touch with.

Another subject discussed was heavy rain. The first question--can we characterize it? We think the answer there right now is no, but we certainly think that this is a worthwhile endeavor, and we should press on with this activity. It may be that in the future this kind of problem, when it is detailed better, may lead to some design changes or operational procedure changes. It is certainly something to keep in mind.

Related to operations in storms and heavy rain encounters is the microburst wind shear problem. We don't think we can characterize it. We would recommend that both the heavy rain and the microburst people stay in close touch because the two problems are probably related. We will be anxious to hear your reports and progress.

With regard to turbulence, we identifed this phenomenon as that characteristic of nonsteady atmospheric conditions that involves structural design considerations. We feel that we're pretty well along in characterizing the turbulence characteristics of the atmosphere. It cannot be avoided. The technology is ready, but as we go more and more into the sophistication of advanced flight controls, digital controls, etc. we're going to lean more heavily on the knowledge that we have and put more dependence on that knowledge. If more knowledge could affect our atmospheric modeling practices, we want to know about it. Right now, we think we're in pretty good shape with regard to the definition of turbulence in the air.

Icing conditions and consequences are pretty well characterized for transports that operate at high altitudes. For lower altitudes, there is much work that needs to be done. We concluded from our discussions that it is being identified and that people are pursuing this need. We discussed frost, and we do not think that frost is an important design problem at the present time. Again, research findings should be highlighted at these workshops, and we'd like to be kept advised.

A lot of these findings and conclusions are repetitions of things that people have said up here in previous years. However, there are two new ones that should be highlighted. They are very worthy of further investigation--namely, the work going on to understand heavy rain and the microburst phenomenon. Understanding of these two problems could influence design and operations, enhance safety, and are certainly worthwhile projects.

Question and Answer Discussion:

Byron B. Phillips, NCAR: I wonder if you could itemize which parameters of heavy rain you feel that you are unable to characterize?

Richard L. Foss, Lockheed, California Co.: I think we need to know more about the concentration of the water. Whether there is some related changes in wind velocity and direction is kind of fuzzy in my mind. It just seems like there is a new idea here, and some people have taken that idea and looked at the impact of it and said that it could have a big effect. We've looked at some airplane incidents, and we can relate the two, maybe. I don't think it's even a firm yes on that, but on what basis I don't think we know enough yet to really pin it down.

John McCarthy, NCAR: Of course, we have a large amount of Doppler radar data now, in multiple Doppler and single Doppler cases. The case that I showed on the microburst is very well documented in terms of the total amount of rainfall

or precipitation water in it. We've discussed this with Dick Tobiason and Jim Luers, and when you say we can't characterize it, I don't agree. We can characterize it; the data exists. It hasn't been looked at in this particular framework, but we've got a ton of data at NCAR, Severe Storms Lab, to do just this. The correlation work needs to be done. The data is there, and I think that you can characterize it. I strongly urge that that be done, and we'll help in any way we can.

Richard L. Foss, Lockheed, California Co.: Very good point.

SUMMARY REPORT: METEOROLOGY IMPACT ON AIR TRAFFIC CONTROL SYSTEM DESIGN COMMITTEE

Members: James R. Banks, Chairman; ATC Consultant

John Blasic, NWS Rep to FAA

Michael J. Bliss, Flight Instructor

Robert E. Carr, NASA/WFC

*John W. Connolly, Alden Electronics Co./UTSI

*Wayne Higginbotham, Independent

John W. Hinkelman, Jr., FAA Rep to PROFS Program

George A. Lucchi, Sperry Flight Systems

*Frank Van Demark, FAA/Systems Development Division

Introduction

After looking at the topic areas of the Fifth Annual UTSI Workshop and how they were divided into very precise disciplines, and how the topics contrasted with the rather broad air traffic control (ATC) topic which not only encompasses the other disciplines but a myriad of other activities, the ATC Committee assumed somewhat of a catalyst role in determining how, and to what extent, the weather related disciplines impacted on or correlated with ATC system design. Viewed in that perspective, the topic area becomes after addressing the troublesome areas one of "Assessing the feasibility of meteorological considerations being integral to the ATC system, hence influencing system design to accommodate the accumulation and distribution of aviation weather in its various forms."

Discussion

Addressing the topic of ATC in its broadest sense, we are dealing with a composite of systems or factors, i.e., airplanes, controllers, pilots, meteorologists, regulations, and weather phenomena in its many forms and their adverse effects on flying operations. We are also dealing with the various technological preparations and training to cope with this environment. Notwithstanding this consolidation of various aspects of aviation support under the broad ATC system umbrella, it is essential not to misinterpret the fundamental role of ATC, especially in the areas where meteorology must be considered in the context of what weather conditions must be conteneded with (or if hazardous, avoided) as identified with instruments flight vis-a-vis what weather must be avoided as identified with VFR flight.

We are confronted with basically two distinct categories of flight in relation to the navigable airspace environment. The IFR aircraft where air/ground communication is usually maintained with the ATC facility (or system center or TRACON) and where separation responsibilities are the first order of business. Today, these facilities by design are not the principal conduits for passing weather advisories to IFR aircraft. They do, however, rely on timely weather data in making control decisions. Moreover, they (controllers) routinely recognize the significance of critical weather information and share such with the pilot on a useful basis. The recognition and proper use of adverse weather information is integral to controller responsibilities. However, the controller's reactions to the influence of adverse weather may address a broader scope of decision making than the individual pilot receiving the same information.

VFR flights may or may not operate in the ATC system. Recognizing that VFR may represent a non-flight planned operation without two way radio communications or transponder in uncontrolled airspace (and all too often, presenting an operational hazard to other aircraft in controlled airspace) and operating unknown to anyone else -- OR -- the VFR may represent a fully equipped aircraft operating under a radar advisory service that quite firmly considers the aircraft to be within the defined parameters of the ATC system.

* Part-time

A network (or matrix) of Flight Service Stations (FSS) throughout the CONUS perform a flight following service to VFR aircraft operating in accordance with a pre-filed VFR flight plan. In addition, the FSS may provide a myriad of services to all aircraft seeking flight information and having the capability - and are so inclined to do so - to communicate with them. Services include the dissemination of weather information as received from various government weather observation and forecasting services plus local observations taken by an accredited FSS specialist. Dissemination of meteorology information is via pilot briefings and periodic broadcasts. Hourly weather sequences pertaining to the more active terminal areas plus SIGMETs and PIREPs are passed to ATC facilities and subsequently to the affected pilot if adversely affecting his/her planned flight, or otherwise on a workload permitting basis. Weather data pertinent to the terminal area may be recorded on the ATIS.

Problem Areas

It quickly becomes evident that ATC system accommodated flight may represent aircraft in contact with the center, approach control, control tower, flight service station, and intermittently with the company. In order to cover this segmented environment and ensure pilot receipt of timely and quantitative weather information, weather observations, forecasts, PIREPs, SIGMETs, etc. must be collected, processed, and disseminated in a relatively short period of time. These are perishable data subject to rapid deterioration. Therefore, weather flight data dissemination methods must be designed to meet all concerned users on an effective basis. Moreover, to reach pilots in a timely manner, these methods should not depend on activities that consider weather dissemination a secondary or non-function.

The ATC Committee concluded that there are signicant problem areas surrounding the collecting, processing, and dissemination of important weather information. Pilot access to real-time weather information is at best, a fragmented proposition. The "first man through" practice where the observed weather is passed to succeeding aircraft is still a mainstay in obtaining the general weather picture on a real-time basis. Such falls into the PIREP category. Too frequently, they are not pumped back into the dissemination system in time to benefit other users -- perhaps not at all.

Recommendations

After meeting with the Icing, Fog, Lightning, Ozone, and Wind floating committees, the ATC Committee identified the following problem areas and made its recommendations. The areas of general consideration are:

General Considerations:

1. ATC system design flexibility to accomodate critical environmental hazards and their impact.
2. The evolving role of the ATC system and its controllers in weather related data dissemination as a result of changing conditions, i.e., economic (fuel costs etc.), safety, better quantitative weather sensors, and capability to more precisely predict weather situations.
3. Pilot education in recognizing and dealing with weather.

Icing and Frost:

Recommend (or otherwise support Icing Committee recommendations):

1. That NWS provide better definition of areas of potential icing conditions, provide an icing criteria (coded levels) without specific qualifications.
2. Consideration of use of airborne liquid water content sensors for providing information on potential icing areas.

Lightning:

Recommend (or otherwise support Lightning Committee recommendations):

1. That NWS and FAA analyze and test usefulness of available lightning data to better define convective storm hazards.

Fog:

Recommend (or otherwise support Fog Committee):

1. The development of automated airport weather sensors to provide critical parameters necessary to operate out of the various types of aerodromes, emphasizing air carrier, commuter, etc. requirements at non-controller airports with instrument approaches.
   Action: FAA
2. Recommend improved low-cost visibility sensors and/or markers.
   Action: FAA/NWS

Ozone:

A need exists to better define purpose and intent of a new FAA regulation pertaining to aircraft operations in ozone areas. On the surface, it appears that the ATC system can within reason accommodate any realistic requirement placed on it in this areas. However, it would seem more logical to treat the symptom rather than place yet another responsibility on the ATC system. Recommend FAA investigate the feasibility of sanitizing aircraft pressurized compartments with a conditioned source of air or cost effective alternative to catalytic converters.

Winds:

Recommend:

1. The ATC system be enhanced to provide operational assistance to pilots regarding hazardous areas (convective, orographic, CAT, turbulence, etc.) and in view of envisioned controller workloads generated, perfecting automated transmissions (data link) containing this type of information to the cockpit as rapidly and as economically practicable.

2. Finally and most important, that the FAA, NOAA, NWS, and DOD jointly address the problem of fragmented meteorological collection, processing, and dissemination problems pursuant to developing a system dedicated to making effective use of perishable weather information.

In other areas, the ATC Committee's attention was invited to the existence of a rather unbelievable situation whereunder a prospective pilot could incorrectly answer all weather related questions on a licensing examination and still obtain a license to fly. Moreover, the training syllabus focuses more on identifying weather phenomena than coping with it. It seems apparent that a serious deficiency exists in pilot training as it relates to weather. Such recognition mandates a recommendation to the FAA to thoroughly examine pilot training programs pursuant to eliminating that deficiency.

Summation

The various methodologies for assessing weather phenomena (ice, fog, turbulence, wind shear, etc.) is fragmented and disorganized. Avenues to the pilot needing critical weather data are largely not responsive to those needs. The utilization of ATC system resources to disseminate weather data is a recognized part of ATC when such data is directly related to control decisions. However, the recognized attributes of ATC as being the most direct access to the pilot does not permit the ATC system to become overloaded with weather data that has a secondary significance in total system considerations. Moreover, the ATC system is being solicited to disseminate information which, thus far, means have not been identified or established for its prediction or otherwise collected for dissemination.

Should the ATC system, in future configurations incorporate provisions to disseminate weather information on a more complete and quantitative basis without impact on primary ATC responsibilities, dedicated manpower should be considered for that role.

SUMMARY REPORT: WINDS, WIND SHEAR, AND TURBULENCE COMMITTEE

Members: Robert J. Roche, Chairman; FAA

John H. Bliss, Flying Tiger Line

Warren Campbell, NASA/MSFC

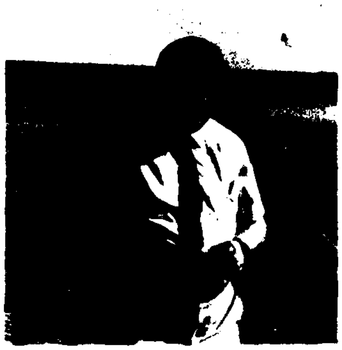
Dagfinn Gangsaas, Boeing Commercial Airplane Co.

John McCarthy, NCAR

William A. R. Robertson, ALPA

Frank B. Tatom, Engineering Analysis, Inc.

S. T. Wang, FWG Associates, Inc.



Introduction

Walter, I too appreciate the opportunity to participate in this workshop, and particularly I've enjoyed encountering the various disciplines, and I have to mention particularly the airline pilots who've joined us.

To the extent that the standing committees have faithfully reported out recommendations resulting from their interfacing with our committee, everything that I have to say will be redundant. I could stop there if you're running behind time. The discussion of the Wind, Wind Shear and Turbulence Committee focused on two areas of discussion. The first area was to improve operating efficiencies, and the emphasis here was the need for improved real-time winds aloft and temperature data for improved flight planning, and the need for improved numerical forecast modeling using real-time wind and temperature information. The emphasis was placed on developing the interfaces and means of utilizing data that already exists and is being collected daily by the airlines but does not become a part of a common data base.

The second area that was broadly discussed was increased flight safety through improving the detection and real-time reporting of hazardous weather information simultaneously to pilots and controllers with emphasis on thunderstorms and the downburst or microburst phenomena which create the strong vertical and horizontal wind shears and through improved flight procedures, particularly on approach and landing to avoid the serious degradation of aircraft performance if a wind shear condition is encountered. These two topics kept coming up in practically all of our committee interfaces, and I emphasize those in the front because they take priority in terms of our recommendations. The committee also wants to strongly endorse the Joint Airport Weather Studies (JAWS), the JAWS program that was highlighted by John McCarthy in this workshop. This three year program will provide data and answers to many of the problems which were addressed as we interacted with the standing committees and which appear in many of the committees' recommendations.

Discussion

Now I will address our interfacing with each of the standing committees. The first was efficiency. A problem was poor winds and temperatures aloft information.

The first recommendation is making available to all users existing data being collected by the airlines through AIRINC. Those involved in this recommendation include the airlines, AIRINC, NOAA, NASA, and FAA.

The second recommendation would be conducting a cost/benefit study to highlight the benefits that can be realized domestically through the use of a common winds and temperatures aloft data base and through improved collection of such data either through additional reporting or by automatically reporting with automated sensors on aircraft. NOAA, NASA, FAA, and the airlines should be involved in implementing this recommendation.

The third recommendation is encourage or demand an operational ASDAR as soon as possible. The airlines and other users should be supporting

that recommendation.

Another recommendation is developing a capability for very accurate (we're talking about say four to six minutes, plus or minus) forecasts of wind changes which would require terminal reconfigurations or changing runways. The NOAA PROFS program would have responsibility for this recommendation.

The last recommendation under this problem was to develop improved numerical weather prediction of winds and temperatures aloft. NOAA would be responsible for this recommendation.

Another problem is inadequate detection of clear air turbulence. The first recommendation is investigating what has happened to the promising detection systems that have been reported and recommended in previous workshops. The airlines, NOAA, NASA, and FAA should address this recommendation.

The second recommendation is to improve the detection and warning of clear air turbulence by developing new on-board sensors as well as continuing developing emerging technology for ground based sensors. NOAA, NASA, and FAA have responsibility for this recommendation.

The Simulation committee: We addressed three problems with one solution. The problems include the fact that there is totally inadequate high resolution data, and therefore, inadequate models existing today on thunderstorms and convective microburst events causing low level wind shears. The second problem is determining how much training is required of pilots using wind shear aids. Low level wind shear models used today may have a negative training effect because of the lack of fidelity of those models. The third problem requires calibration of numerical flight performance models using flight simulators with pilots to design a real-time warning system using Doppler radar. The idea here is that we want to acquire accurate parameters that would identify when there was a hazardous condition.

The recommendation for these three problems is collecting the data that will provide three and four dimensional wind shear models. Once again, the proposed JAWS program should provide this and is highly recommended. The National Science Foundation, NOAA, NASA, and FAA are involved in this recommendation.

In our interface with the Procedures Committee, one problem addressed was, or I might comment, that there's some need to check the accuracy of this recommendation. We're talking about the current advisory circular on wind shear penetrations, and we didn't have a copy of that with us, so we weren't sure of the exact wording, but there is concern that this advisory circular is based in part on information that came out from Boeing, and Mr. Higgins has been mentioned as involved in writing that recommendation regarding the stick shaker solution upon encountering wind shear. We feel that at this time the advisory circular may be poorly or inaccurately written which recommends immediately pulling to stick shaker upon encountering wind shear. Use of this procedure results in dissipating all available energy in an inefficient way as it immediately places the aircraft in a higher drag regime. The recommendation is that the advisory circular be changed to recommend the procedure to hold at whatever airspeed that the aircraft has when the pilot realizes he's encountering a wind shear and apply maximum power, and that the pilot would not pull to stick shaker except to flair when encountering ground effect to minimize impact, or to land successfully or to effect a go-around. FAA would have responsibility for this recommendation, and we will check on the accuracy of our recommendation before we continue with this recommendation in the written proceedings.

A second problem discussed was that current wind shear detection and warning systems are inadequate. The recommendation is broad in that many systems, whether airborne, or ground, that can provide advanced or immediate alert to pilots and controllers should be pursued. Two approaches are particularly emphasized. The first is that the pending notice of proposed rule-making (NPRM) on the proposed airspeed, ground speed procedure should be issued. I would make a reservation here in that some of the members of our committee aren't sure of what the wording is, and all that is included in the pending notice of proposed rule making, but our committee feels that regardless of this, the proposed NPRM does include the airspeed, ground speed procedure, and that it should be issued so that we can get on with the rule making action and receive comments on the NPRM.

A second approach emphasized is the need for continuing the development of Doppler radar technology to detect the wind shear hazard, and this should be continued at an accelerated pace. Any Doppler radar system proposed should be tested with the data which should come from the JAWS program. The FAA and the NEXRAD-JSPO are involved in this recommendation.

Another problem discussed is that the current pilot population is not aware of the full range and magnitude of wind shear events which may be encountered. The recommendation is to provide improved training to all pilots on wind shear phenomena and particularly pilots of high performance, corporate, and commercially used aircraft. Emphasis should be placed on using the microburst phenomena where medium strength downdrafts convert to very strong horizontal winds spreading outward from the centroid of the cell and which will result in very strong head winds switching to very strong tail winds within potentially a two to three kilometer distance. The airlines, users, and FAA are involved in this recommendation.

Another problem in today's high traffic environment is that flight operations are conducted in precipitation in close proximity to severe weather. Many airlines are equipped

with X-band radars which have a more severe weather return performance due to attenuation as compared to C-band. Now, I might mention that there is a trade off between X-band and C-band wherein, while C-band provides better performance in terms of identifying the rain cells in heavy rain; X-band provides better resolution particularly at a distance. So, there is a reason why airlines have favored and pilots like X-band today. However, because of the continuing occurrence of fatal accidents as a result of aircraft flying into severe thunderstorm cells, we feel that this trade off is clearly swung to the need for better reduction in attenuation or going to the C-band radar. Therefore, the recommendation is that airlines should switch to C-band radars when purchasing new equipment or replacing existing radar equipment whether conventional reflectivity radars or in purchasing new airborne Doppler radars. I might comment that this is the same recommendation that was included last year. The airlines and the FAA should address this recommendation.

In our interaction with the Design Committee, we didn't identify any substantial need for improved turbulence characterization in the area of design. Enough information is known. In a second recommendation, there is a need for airline manufacturers to take into consideration the effect of phenomena such as microbursts which produce strong periodic longitudinal wind perturbations at the aircraft long period phugoid frequency, and this is addressed to the manufacturers. There is a recommendation which endorses JAWS from this committee. The last recommendation from this committee was to consider gust alleviation devices on new aircraft to provide a softer ride through turbulence. This would be addressed to manufacturers.

In our interaction with the ATC Committee, problems include how well the ATC systems deal with the dissemination of new sensor information, for example, Doppler radar detection of the wind shear phenomena. Controllers are often too busy to pass these kinds of weather data to pilots. The recommendation is developing systems to automatically detect hazardous weather phenomena through signature recognition algorithms and automatically data linking alert messages to pilots and controllers. Future ATC systems should be adaptable to receive and utilize quantitative hazardous weather information. These future systems must include the simultaneous up-linking of flight data or to the flight deck of the same information. The FAA and avionic manufacturers are involved in this recommendation.

Question and Answer Discussion:

(unidentified person commented): I think it would make good sense in future years to incorporate the heavy rain phenomena discussions into the wind shear discussions because of the close relationship, or the potential close relationship between the two, rather than treat them in two separate committees. The second recommendation that I'd make would be that the entire subject be submitted for binding arbitration.

Robert Roche, FAA: We were hopeful that we would have interacted with the committee who had that responsibility, but they are a floating committeee, and floating committees don't interact. I agree with the recommendation.

Walter Frost, UTSI: The one that is troubling me a little bit about all the discussions that have taken place on wind shear on this committee as we've addressed only microburst wind shear, and there are other forms of wind shear that have proven hazardous. I was wondering if your committee discussed at all the number of general aviation accidents which may occur not only due to wind shear but also to terrain feature effects or building shedding. I'd be willing to bet that off the Gulf coast a number of these helicopter accidents may have been associated with strange wind phenomena around the off-shore platforms. Was there any discussion to that effect?

Robert Roche, FAA: Your're correct that there was not.

SUMMARY REPORT: ICING AND FROST COMMITTEE

Members: Harry W. Chambers, Chairman; U.S. Army Aviation R&D Command

Herb J. Coffman, Bell Helicopter Textron

Mark Dietenberger, University of Dayton Research Institute

Peggy L. Evanich, NASA/LeRC

Sepp J. Froeschl, Canadian Atmospheric Environment Service

Richard K. Jeck, U. S. Naval Academy

Prem Kumar, FWG Associates, Inc.

Pete W. Speck, Wright Patterson AFB

Grady W. Wilson, Edwards AFB

General

The committee identified six priorities with respect to recommended actions requiring further R&D. Of the six priorities, the first three are so interrelated that they should essentially be studied concurrently, and agencies conducting the studies should closely interface. The priorities are:

- Full scale in-flight simulation capability for development of deicing/anti-icing systems and certification of helicopter flight into icing conditions.
- Definition of the low altitude ($\leq$12,000 ft MSL) icing environment for deicing/anti-icing design and certification of helicopters and airplanes for flight into icing conditions.
- Improvement in reporting timely icing conditions using parameters which are useful to pilots.

The most logical approach to the preceding is to define the icing meteorological environment at the low altitudes first. Secondly, when the environment has been defined, then specific requirements exist to develop reporting parameters which are useful to the pilot. Thirdly, and obviously not last, is a real world requirement for the full scale in-flight icing simulation capability for helicopters and general aviation airplanes at a reasonable cost. Under the assumption that the three preceding requirements are essential to insuring safe operations of helicopter and general aviation airplanes under specified icing conditions, the following is discussed.

Icing Simulation Capability

Numerous facilities exist in North America for conducting research and development of engine and airframe components for optimizing designs for operation under icing conditions. Currently, there exists ten icing wind tunnel facilities, twenty-five engine icing test facilities, fourteen low velocity icing facilities, and five tankers for in-flight icing simulation testing.

Existing wind tunnels have the capability for producing icing conditions to cover the FAR-25 envelope and the entire altitude and velocity range of test aircraft. Unfortunately, only aircraft components (i.e., engine inlets, tail sections, wing sections, etc.) can be tested, and helicopter rotor blades are just simply too large. Engine wing test facilities are excellent, and certification of engine and engine inlets are standard procedures. Low velocity facilities are generally used for sea level cold room tests of equipment; however, an icing spray rig in Ottawa, Canada exists which can be used for helicopter hovering icing tests. The gapping hole in the certification process of helicopters and general aviation airplanes is adequate substantiation of the entire aircraft to FAR-25 icing certification requirements.

The U.S. Army, U.S. Air Force, Cessna, Piper, and Flight Systems Research have developed in-flight icing capabilities. However, the only capability that can almost produce an icing spray sufficient to immerse a complete helicopter or light airplane is the U.S. Army's Helicopter Icing Spray System (HISS). The HISS is a CH-47C helicopter which produces an ice spray cloud 3 x 12 meters that closely approx-

imates the water droplet size and distribution found in nature.

The HISS is undergoing improvements, and it is hoped that eventually the cloud size can be increased to approximately 6 x 20 meters, and the liquid water content (LWC) capability increased from 1 g/m^3 to 3 g/m^3 so that current FAR-25 requirements can be met. The cost of the HISS is expensive and currently approaches $500,000 for 20 hours of flight testing. The cost can be reduced provided more than one project is conducted concurrently by the U.S. Army.

Even with the preceding capabilities available for R&D as well as for icing certification of helicopter and general aviation airplanes, there is a real need for a national full scale, in-flight icing simulation facility (airborne tankers). The facility would be used for the research, development, and certification of helicopter and general aviation airplanes for flight into icing conditions necessary to meet FAA certification requirements. The purposes for having the facility are:

- To test the aircraft as a complete flight system. Currently, there are no ground based facilities large enough to test a full scale helicopter or airplane.
- To demonstrate for certification of deicing and anti-icing protection systems the extreme icing conditions which are difficult to find in the atmosphere.

The development of such a facility must include a R&D program to assume that natural icing conditions are properly simulated. Adequate instrumentation must be available to measure LWC, water droplet size, droplet size distribution, humidity, radiation, and temperature at or near the area of ice accretion. Furthermore, the types and characteristics of ice formations made from simulated icing using spray nozzles must be determined to be the same as that formed by natural icing conditions. Even though airspeed, temperature, LWC, droplet size, and droplet size distribution are duplicated under both simulated and natural icing conditions, the resulting ice accretion shapes and types of ice on a collecting surface are not the same for both conditions. The reason for the discrepancy could be due to the amount of super cooling, if any, of the droplets formed by spray nozzles. Icing clouds formed by spray nozzles are also inherently non-uniform in water concentration both in cross-section and longitudinally. Thus, local measurements must be made in the area of the ice accretion.

The high cost of developing an in-flight icing simulation capable of duplicating the FAR-25 icing environment necessary for certification of helicopter and general aviation airplanes is obviously prohibitive in the civil sectors. The most reasonable approach lies in the development of a DOD system available to the civil sector. Towards this end the FAA and U.S. Army have been jointly involved through interagency agreements for the past three years to conduct research and development leading to an in-flight simulation capability. This capability would provide that necessary to meet FAA FAR-25 icing certification requirements.

As a result of effort to date the HISS now produce an ice spray that almost duplicates the natural icing environment. However, much more development efforts are required to develop a cloud that can produce 3 g/m^3 LWC for a reasonable period of time with the correct water droplet size and distribution while immersing the complete aircraft. In the meantime, it is recognized that maybe the FAR-25 icing environment for helicopters and general aviation certification requirements is not realistic and less stringent certification requirements are applicable . Consequently, if the low altitude icing environment at which helicopter and general aviation airplanes are expected to operate (≤12,000 ft MSL) are statistically less severe than what the FAR-25 requirement specifies, then, to over design in-flight icing simulation facilities is cost ineffective.

This now leads us into the very necessary requirement to define the low altitude icing environment so that a realistic design approach is taken for development of a suitable in-flight icing simulation capability for FAA icing certification requirements.

Definition of the Low Altitude (≤12,000 ft MLS) Icing Environment

Current icing certification requirements contained in FAA FAR-25 Appendix C were developed from old NACA data (1950 time frame) gathered world wide at all altitudes. The highest LWC encountered during actual in-flight icing conditions was a LWC of 1.9 g/m^3. The application of statistics to obtain a 99.9 percent probability of encountering a higher value was obtained and determined to be 2.9 g/m^3. Recent re-evaluations of the NACA data as well as flight testing to gather new meteorological data internationally has indicated that the lower altitude icing environment is much less severe than FAR-25 Appendix C requirements. As a result, the current FAA icing certification requirement may be too severe and result in either the inability of aircraft manufacturers to produce effective anti-icing or deicing systems or to produce them cost effectively. The U.S. Army recognized the possible inconsistency of the NACA data and FAR-25 Appendix C certification icing requirements and subsequently considered that approximately 2 g/m^3 to be a more realistic certification requirement for unrestricted flight into icing conditions. The U.S. Army has more recently designed complete helicopter deicing and anti-icing system protection for the UH-60A and AH-64 helicopters to a level of 1 g/m^3. This effectively protects the helicopters in moderate icing conditions.

Based on the preceding it becomes obvious that new design and certification icing criteria should be established for low altitude aircraft. Restricting aircraft to low altitude during icing encounters would allow ice protection systems to meet less severe icing conditions that are presently defined in FAR-25 Appendix C. This would be a significant economic benefit to the development of all weather helicopters and general aviation airplanes that could meet more realistic icing certification requirements. The development of new design and certification icing criteria should include:

- Review of historical NACA data used as the basis for the long standing FAR-25 Appendix C criteria at various altitudes.
- Acquisition, integration, and interpretation of the extensive icing cloud data collected, since FAR-25 developments, with the NACA data.
- Expansion of the current effort to collect and thereby augment the existing very low altitude icing cloud data.
- Analytical effort using statistical procedures on all of the above data sources to determine if a sound basis exists which would justify new relaxed icing certification criteria restricted to low altitudes.

The FAA and NASA are currently engaged in efforts to define the low altitude icing environment. The use of historical data and the possible merger of old data with more recent data has raised the issue of the degree of validity of the historical measurements because of the limitations of the earlier icing instruments. A comparison of the old instruments with more modern types under natural icing conditions is required to assess the level of reliability of the old data in light of perhaps better measuring techniques now available.

Even though more realistic icing certification requirements and definition of the low altitude icing environment can be determined, there still exists the requirement for timely and accurate icing conditions to pilots. This leads to the third prioritized important consideration for integrated research and development.

<u>Improvement in Reporting Timely Icing Conditions Using Parameters Which Are Useful to Pilots</u>

The current procedures for defining icing conditions to pilots are qualitative and open to significant errors in reporting. The use of terminology such as trace, light, moderate, and heavy ice is subjective and highly influenced by the ice accretion characteristics of different aircraft. Additionally, the pilot "panic" factor can greatly influence reports of icing. It is not uncommon for inexperienced pilots to report light icing as heavy, and old "seasoned" pilots to report heavy ice as light or moderate. In other words, there is no quantitative values that are currently used to report icing conditions. This can be mainly attributed to aircraft not being equipped with instrumentation for measuring LWC, ice accretion rate, etc. Only recently has the U.S. Army defined icing severity in quantitative terms of LWC and temperature. The current definitions used by the U.S. Army are: trace ice is a LWC of .15 g/m^3 or below; light ice is .15 to .5 g/m^3; and heavy ice is .5 to 1.0 g/m^3. The newest U.S. Army helicopters qualified (U.S. Army qualifies while FAA certifies) for flight into icing conditions are equipped with LWC meters, temperature probes, and ice detectors, and have LWC directly displayed to the flight crew. Consequently, the crew is continuously aware of the icing environment.

Currently, PIREPs are used in coded format from flight crews to FSS via voice message. Then, there is a manual screening and entering of PIREP messages into service "A" network by FSS personnel. The current system deficiencies can be divided as follows:

- Icing terminology is qualitative and ambiguous.
- Reported icing intensities are subjective.
- PIREPs often are not generated by air crews experiencing significant weather conditions.
- PIREPs are random and infrequent.

Improvements are essential to the current system of reporting icing conditions that are useful to pilots. Both the reporting parameters and the speed at which these parameters are provided to the pilot need to be improved. The present qualitative categories of icing intensity are unsatisfactory. A condition reported light by a 727 flight crew would be considered heavy for a light aircraft, thereby creating a dangerous situation.

The icing condition needs to be put in terms of the basic parameter of LWC, temperature, and extent of the icing condition. The severity of the icing conditions could then be based on the values of LWC and temperatures similar to how the U.S. Army has done it. Additionally, aircraft certified to LWC, temperature and exposure time have known ice accretion characteristics based on quantitative parameters. This is a definite asset when icing conditions are reported in terms of LWC and temperature since the pilot will know the aircraft capabilities based on those determined during certification trails. When the aircraft is equipped with appropriate instrumentation, the pilot can determine if flight into the known conditions is safe or alternate action must be taken.

To implement the preceding procedures it will require the availability of a low cost and reliable LWC meter and its installation on aircraft and/or radiosondes that frequent much of the airspace in which icing conditions are prevalent. One such instrument could be the old NACA pressure-type icing rate meter which was

specifically developed for wide distribution on aircraft operating on routine schedules. This meter could be updated to take advantage of modern electronics for readout and data acquisition. Aircraft equipped with electronic airspeed sensors could acquire direct readings of LWC by integrating airspeed with icing rate. The qualitative value of the icing condition, thus, measured could be transmitted by means of the ARINC Communications Addressing and Reporting System (ACAR) or other aircraft meteorological data relay (AMDAR) system and then, distributed as PIREPs by the NWS.

Experimental and developmental programs are required to evaluate the use of LWC meters and temperature sensors on scheduled low altitude aircraft (such as commuters and airlines). Additionally, the evaluation of automatic telemetering (similar to or part of the AMDAR system) of quantitative values of LWC, OAT, IAS (or TAS), FL, aircraft ID, and position to FSS or other ground receiver and computerized data system should be conducted.

SUMMARY REPORT: ATMOSPHERIC ELECTRICITY AND LIGHTNING COMMITTEE

Members: Charles F. Schafer, Chairman; NASA/MSFC

Rudy C. Beavin, AFWAL/FIEA

John Prodan, AV-CON Corp.

Joseph W. Stickle, NASA/LaRC

William W. Vaughan, NASA/MSFC

Introduction

The floating-fixed committee arrangement used this year permitted a greater range of interaction among the participants. Due to the (perceived) overlap in interests of the committee members, some repetition of discussions was inevitable as the floating Atmospheric Electricity and Lightning Committee moved from session to session. These reiterations of the same topics probably have a very positive role; however, in that they tend to underscore areas of general concern.

Discussion

The observation and recommendations made by the Atmospheric Electricity and Lightning Committee of the 1980 workshop are still considered valid in general by this year's committee. Some of those were:

1. Need for research in the areas of:
   - a.) lightning stroke models
   - b.) application of electric field data to prediction models
   - c.) use of satellites and Doppler radar in thunderstorms detection and lightning forecasting
   - d.) electric field measurement instrumentation (airborne/ground based)
   - e.) on-board instrument (e.g., magnetic strips) to detect lightning strike current paths on aircraft
2. Need for improved data base:
   - a.) improved strike reporting by aircrews
   - b.) consider data bank for lightning strike information
3. Need for training users in the interpretation of data from devices which indicate electrical activity (e.g., electric field measuring equipment, lightning detectors, and Doppler and weather radar).

One specific reservation was that the case for a National Flying Lightning Laboratory should not be augmented until after more results are in from the NASA F106 flight program and the Air Force C130 flight program.

The workshop was advised of plans to conduct an Atmospheric Electricity Hazards Protection (AEHP) Advanced Development Program (ADP) administered by the Flight Dynamics Laboratory of the Air Force Wright Aeronautical Laboratories (AFWAL/FI). The ADP will be sponsored jointly by the DNA, FAA, NASA, U. S. Army, U. S. Air Force, and U. S. Navy to establish protection criteria for electrical and electronic systems aboard rotary and fixed wing aircraft and cruise missiles. The joint sponsorship will assure affective resource applications to address mutual problems. In addition, all agencies will be afforded an opportunity to contribute their unique technical and operational skills and understandings to the problem. The effort is expected to be started in late 1981.

The workshop was also advised of NASA plans for the development of a geosynchronous satellite borne lightning sensor. The initial concept involves an optical sensor to continuously monitor lightning discharges with a focus on the United States. Sensor design studies are expected to start in FY81.

SUMMARY REPORT: FOG, VISIBILITY, AND CEILINGS COMMITTEE

Members: Byron B. Phillips, Chairman; NCAR

Frank Collins, UTSI

Don S. Cornwall, ALPA

Joel M. Graybeal, University of Maryland

Otha H. Vaughan, Jr., NASA/MSFC

Edwin A. Weaver, NASA/MSFC

I also would like to thank Walter Frost for the hospitality of UTSI and to thank the sponsoring groups who have supported the workshop. I am one of those who came somewhat reluctantly thinking thoughts that have changed quite drastically during the workshop. It's been stimulating and informative for me to participate among such a wide spread diverse group. I think that many of us are operating somewhere in the Peter's principle regime when we are faced with the tremendous number of disciplines which we see involved in this conference.

Introduction

The Fog Committee has several recommendations, some of which coincide with recommendations that have been expressed by other committees. The committee reviewed the status and impact of fog, reduced ceilings and visibility with the various fixed committees at the workshop. A Current Status Report as evaluated by the Fog and Visibility Committee is attached. Generally, the aviation flight industry can be divided into three groups: Military, large commercial carriers, and general aviation. In this grouping both business aviation and the commuter type airlines are included in the category of general aviation. It appears overwhelmingly that the principle impacts of fog, reduced ceilings and visibility are to general aviation. This is true at present and will continue to be true for the future.

Discussion

The primary impacts of fog, and of reduced ceilings and visibility are on aircraft operations including areas such as flight planning, successful completion of the flight, diversion to an alternate terminal, terminal conditions at either the origin or the destination airports, in-flight delays, safety, etc. The results of the impact on operations unquestionably is a major reduction in the overall efficiency of aircraft operations for both commercial carriers and general aviation alike. The large delays both on the ground and in the air during prevailing periods of restricted conditions are perhaps most costly and cause the most apparent disruption of the commercial carrier fleets. This is in part because the private and the business aircraft are more flexible in flight planning than are the scheduled airlines and will tend to stay down during periods of continued restrictions or will divert to alternate airports.

None the less, the committee's judgment is that the overall impact of fog and reduced ceilings and visibility is greatest for general aviation. General aviation is by far the largest of the operating groups. Pilot training and proficiency may be lower. Flights are conducted from and to more marginally instrumented airports which often are without local, timely weather observations. Aircraft instrument flight avionics are less adequate in many of the aircraft used by general aviation. Weather data and route forecast disseminations may be restricted, etc. Many of these factors especially relate to flight safety under marginal weather en route and at terminals.

The committee found, during contacts with the fixed committees, there appeared to be no large training-simulator requirements related to fog and reduced visibility conditions. In these two specific areas, the simulation of fog and low ceiling appears to be quite adequte as judged by the pilots reactions to simulation training. In the areas of aircraft design, the committee doesn't recognize any needs in relation to the requirements of the fog and low ceiling restric-

tion. However, that same assessment is not necessarily true and should not be stipulated as regards improvements of aircraft avionics systems.

The specific committee recommendations, reflecting these varied factors as concern the large commercial carriers operating with excellent equipment from well equipped airports on the one hand and as concern general aviation operations with its enormous diversities on the other hand, are prioritized as follows:

Recommendation 1. Research should be accelerated in fog prediction specific to the primary fog impacted airports of the nation with the aim of improving, through mesoscale observation and mesoscale forecast models or systems, the accuracy of the three to four hour prediction of terminal IFR conditions. The priority for this recommendation is partially based on cost-benefit arguments. We feel that there is a large benefit possible from more efficient operations for a small research and development investment.
Responsible Agency: NOAA, University community.

Recommendation 2. A simplified, automatic weather observing system should be developed and installed at other than primary ILS equipped airports which are without present weather observing capabilities. This simplified system should be capable of reporting altimeter, winds, temperature, ceiling and runway visibility less than the VFR minimums to an in-flight aircraft and capable of digital telephone or satellite link interrogation for input to a central data collection system. It seems appropriate that this program be accomplished incrementally beginning first with a two year "Request for Proposal" development-certification-field test at something like 50 priority terminals. This should be followed by annual purchases and installation at the rate of 100 to 200 systems per year at the remaining 500-600 terminals which are now equipped with ILS equipment but without surface weather observations. The presently developed JAWOS which is a more sophisticated system should be installed at the most primary ILS-no FSS observer terminals. We feel that this would modify hazardous flight situations which exists at airports in many parts of the country. It seems especially warranted in certain areas, for example, in the intermountain areas where commuter airlines are coming into mountain fields with low restricted visibility with simply no observations and no information on the terminal weather or runway conditions. It seems also essential for the general aviation aircraft that quite often initiates flights from fields without adequate weather information and arrives at a field that also has no information. Such operations operate almost totally in an unknown environment and are much more subject to pilot error for critical decisions. This is a recommendation that arises from a need for improvement of the safety for these types of flights.
Responsible Agency: FAA.

Recommendation 3 All major commercial air carriers should evaluate the cost effectiveness and the desirability for full Category III operations within their present and planned (1980 decade) operational systems. These studies should be based on the reduced carrier costs and carrier benefits as opposed to the terminal equipment installation and operational costs which will be required. The need for this recommendation is clear because some of the airlines already are recognizing that the airline costs for full Category III operations are not cost efficient for the limited number of Category III landings and takeoffs that they encounter.

For planning proposed by the FAA, by other organizations, we need to know at an early date what are the requirements of the commercial carriers. Certainly, it will be different in certain parts of the country. At Phoenix, Arizona, the commercial carrier will show an entirely different analysis than will a carrier that operates principally in the northeastern part of the country.
Responsible Agency: Air Carriers, Flight Safety Foundation.

Recommendation 4. Research should continue and be encouraged in three major areas:

(a) Taxi-way Category III control systems. This is needed for the movement of both aircraft and emergency vehicles.
Responsible Agency: FAA, AOPA

(b) Warm Fog Dispersal.
Responsible Agency: NASA, FAA, and DOD.

(c) Development of Heads-Up-Display (HUD) airborne microwave or infrared systems which are capable of Category III operations without terminal installations.
Responsible Agency: DOD, NASA, Overnight package carriers.

Recommendation 5. High intensity approach lighting systems should be provided at all airports possessing instrument approach systems. During the discussions it was suggested that these systems could be made capable of random time period operation at the command of the aircraft pilot for emergencies during the night time hours when they're needed but are unattended. This would be an advantageous situation.
Responsible Agency: FAA.

Recommendation 6. Improve the availability of weather educational and instructional material to general aviation pilots through audio and video cassettes, scheduled seminars, public television, and etc. This committee has not limited the recommendation to fog, recognizing that it is a broad scale need.
Responsible Agency: AOPA, ALPA.

As chairman of the Fog and Visibility Committee, I would like to add two observations. First, the opportunity exists for a commercial group to engage in weather route and terminal forecasting on a tailored basis for general aviation using improved NWS data bases. This could be of considerable benefit if correctly done. A second observation is that there does not seem to be an adequate representation of the general avia-

tion community at this workshop. There are some ALPA representatives here but in general the private flyer is not well enough represented. I could recommend some pilots who could contribute very admirably to such a group as this.

That's the extent of the recommendations of the Fog Committee. Once again, thanks.

CURRENT STATUS REPORT

During our initial deliberations, the committee reviewed the Fourth Annual Workshop's Fog, Visibility and Ceiling Committee. The concern of one year ago regarding the need and utilization of Slant Visual Range (SVR), Runway Visual Range (RVR), Visual Meteorological Conditions (VMC), and Instrument Flight Rules (IFR) appears to be no longer valid because of a general acceptance of RVR as an adequate visibility criteria for field operational classification.

In last year's report the committee endorsed the concept of the Joint Automated Weather Observing System (JAWOS). Development of JAWOS is reported to have progressed during the year; however, we presently believe and have recommended that a somewhat simpler and less costly automatic weather observing station based on current development of JAWOS (and perhaps other systems such as the NCAR PAM technologies) should be developed for terminal installations at a majority of the ILS equipped stations not served by other weather observations. JAWOS installations capable of reporting weather phenomena are still required at those reporting stations previously served by FSS observers. However, all AWOS stations should provide data to the synoptic collected data bank where it would be available for aircraft user/pilot flight planning as well as reporting present terminal conditions to in-flight aircraft.

Warm fog dispersal systems were reviewed at the last workshop. Development of the charged particle-electrokinetic/coalescence fog dispersal prototype has progressed at the University of Tennessee Space Institute under the leadership of Walter Frost and Frank Collins and under NASA sponsorship. Prototype tests of a single nozzle system are planned. Thermal-kinetic (the Orly and deGaulle airport systems) have been considered at Los Angeles and Memphis but are not presently projected because of costs.

Cold fog dispersal by dry ice seeding is practiced at very few terminals (Salt Lake and Reno). These dispersal operations are sponsored by airlines.

This year's committee tried to look at CAT III operations in a realistic way. It seems clear that there are three paths to follow when faced with below CAT II minimums:

a.) Live with it - which means that you make the judgment that you will not operate. This decision may be justified on the basis of the frequency and duration of CAT III conditions, the overall costs of not operating (including the public awareness factors), the costs of proficiency training for pilots, equipment costs, etc., vs. benefits. Thus, a commercial airline operating in the southwestern U.S. may come to a different decision than an airline operating along the eastern U.S. seacoast region.

b.) Change the environment - i.e., successfully pursue some fog dispersal technique.

c.) Improve the aircraft/airport sensor/display system to make CAT III landing safely with schedule performance. An example of this is the integrated forward looking infrared millimeter radar aircraft system which was reported by Joel Graybeal of the University of Maryland where the system is being developed under Federal Express sponsorship. This proposed system will provide a parallax-free heads up display (HUD) of the runway through the fog/cloud which would coincide with the visual runway view upon exiting from cloud base. Projected cost is relatively large; however, the sponsoring company has recognized that there are offsetting large benefits in their type operation.

The simulation of fog and low ceilings and visibility were considered to be relatively good as judged by pilots reaction. The Simulation Committee felt least expert in the simulation of ground fog and discussion followed of this phenomena, of possible layering during formation or breakup, of back-scatter light from landing lights during touchdown pitch angles, etc. The psychological impact to the pilot of an "increasing" restriction to visiblity up to and following touchdown was suggested by Don Cornwall (Delta Airlines).

Question and Answer Discussion

Bob Roche, FAA: *I would like some clarification* on your recommendations with regard to low cost automated weather observation systems. Was Joe Sowar in that group? Well, the point I want to make is that FAA has been involved in the development of a low cost automated weather observation system for the past three to four years. We are currently, and I'm not quite sure of the exact status either, beginning tests, or shortly will be beginning tests of a low cost system at Dallas, and we plan to have a similar system at an off-shore oil platform this month, in April. Low cost systems have been developed by industry and are available. They do not include the visibility and ceiling sensors at this time because FAA along with NOAA is testing some commercially available sensors out in Arcadia, and we're trying to complete that work as soon as possible. You did mention the program, the joint program. So, I'm trying to understand your recommendation in light of the fact that industry already has systems that are available. They're

waiting for FAA to complete tests on the sensors that are missing. There's no problem with their incorporating those sensors into their systems. FAA is testing the low cost systems that would be operated by governmental agencies. They would be more costly than commercially available systems because they have to be designed to be maintained by government. If you can enlighten as to the more specific nature of your requests in light of this, I'd appreciate it.

Byron Phillips, NCAR: I don't want to be a gap filler here and try to define something exactly in the middle of all of the developmental efforts. I think it is the committee's feeling that at the ILS terminals, without a weather observer station, that the minimum requirements need to be met and those minimum requirements are altimeter, temperature, ceiling, visibility, wind speed and direction. We've also specified that the data needs to be gotten into a data bank through some system either a telephone interrogation system or a satellite data link, so that the pilot at Podunk, Nebraska can call up and find out what the weather is at Hayden, Colorado. He should also be able to find out when he overflies Hayden, Colorado, what is there before he begins to make his descent so he has some confidence as to what he's going to find or at least the knowledge of what he should find. I think that would contribute a great deal to the safety there. If one of the systems you are developing fulfills those requirements, that meets what we're suggesting exactly; I have the impression that the systems you are developing are either less than that, or require a bit more than that. The JAWOS system is the type of system that reports all the weather phenomena. JAWOS needs to be put at the major ILS terminals. However, you don't need that good of a system at other terminals, so we were making a recommendation with an effort at some cost savings to FAA but an improvement for the overall observing facilities available. I'll talk to you later about that, Bob.

SUMMARY REPORT: OZONE/OTHER METEOROLOGICAL AND ENVIRONMENTAL PARAMETERS COMMITTEE

Members: Arthur D. Belmont, Chairman; Control Data Corp.

Neal M. Barr, Boeing Commercial Airplane Co.

George H. Fichtl, NASA/MSFC

James K. Luers, University of Dayton Research Institute

Porter J. Perkins, NASA/LeRC

G. A. White, III, Wright Patterson AFB

The committee on Ozone and other meteorological parameters considered three different topics: ozone, heavy rain, and acid rain. Each is a separate subject and is presented separately.

Ozone

Arthur D. Belmont, Control Data Corp. (Chairman)

The problem with ozone is toxicity. There are three ways to combat the degree of toxicity in the cabin.

1. filters
2. climatology
3. avoidance by flight planning

The commit discussions dealt with all three of these topics. It was concluded that there are many deficiences at present in our knowledge. These are described below but not necessarily in order of priority.

Forecasts of total ozone. No one has yet come up with a way to forecast total ozone. This is obviously needed if we want to do a good job of flight planning. Assuming we can forecast meteorology, we should include ozone in the forecast also.

Improved techniques to obtain ozone profiles. An improvement over a total ozone forecast would be the ozone profile. Techniques to obtain ozone profiles are currently under investigation.

Availability of meteorological data within three hours. These will be of no value unless meteorological data can be obtained equally as fast.

Unsmoothed NMC analyses. We need more detailed upper air meteorology. The NMC analyses are designed for hemispheric numerical prediction. They are not suited for mesoscale situations such as encountered in stratospheric outbreaks into the troposphere which brings large amounts of ozone into the troposphere at fligh altitude.

Improved tropopause definition. Better tropopause definitions are needed to more clearly distinguish the stratospheric ozone ridge air mass from the tropospheric air. This definition is currently being studied.

Communication of ozone data to ATC and airlines. There is a need to communicate ozone information either as a nowcast or as a forecast to the ATC and the airlines. This one topic keeps coming up in everyone's presentation; more rapid communication of weather locally affecting the aircraft to both ATC and to aircraft is needed. In every one of the committees, I sensed that this was the real problem--faster communication. Much data is measured and known but not relayed to others who could use it, and the same applies for ozone.

Ozone Detection Systems. On-board ozone meters to detect the occurrence of dangerously high levels of ozone are needed. This is controversial, however, because of liability problems. Many airlines do not wish to admit the level of ozone which may occur in the cabin.

Lower cost filters. Certainly, the easiest solution to the cabin ozone problem would be to have very inexpensive filters installed which remove ozone before it comes into the cabin. That is certainly the way to go, but it is not easily done. At present as I understand it, for some types of aircraft there aren't filters available, even on the design boards.

Education/training of crews, dispatchers, ATC, meteorologists, and administrators. Like many of the other fields, there is a great deal of ignorance concerning ozone among many of the agencies and airlines. No training programs to my knowledge presently exist. Flight crews, dispatchers, meteorologists, controllers, and administrators must all be educated.

Ozone is a relatively new problem. Fortunately, so far, it is not a major life-threatening one when compared to other factors, although it does cause concern. It is more a matter of passenger comfort or discomfort rather than a mortality affair. It is a hazard in the same category as clear air turbulence.

The committee recommends that the nine factors described above be addressed simultaneously, if possible. As perhaps the last speaker, I'd like to add my thanks to the organizers, Walt and Dennis for a very interesting and stimulating workshop. It is always interesting to come to a place where there is interaction of many different disciplines. It is much more exciting to talk to people all working in aviation meteorology, but at some distance from each other to see what their problems are. I hope there will be more of this type of interaction in future meetings.

Comment: (unidentified speaker) I think in factor number six Art, you talk about the problem with the airlines. I think we should not forget the high flyers such as learjets which fly up around 50,000 ft where ozone is a much worse problem than the lower stratosphere flyers. I think we ought to specify air space users in general and not just leave it for the airlines. Also, we ought to spell out that more of that will happen in the future.

Arthur Belmont: That's true. I was diffused a little bit last night to hear our guest speaker say that he didn't have any ozone problem because of the high operating temperatures of his engine. I don't know how generally true that is of all small jets. If it is, then they don't have a problem, but if it isn't, they do have. Concord, fortunately, doesn't have the problem.

Corrosion and Acid Rain Report

G. Anderson White, III, AFWAL (co-chairman)

I. Summary. Actions and Agencies.

a.) Awareness that corrosive environment becoming potentially more prevalent.

all agencies

b.) Expand data gathering network for:

1.) suspended particulates

2.) acid rain

3.) Cl^-, I^- ion sampling near oceans

too early to decide agency.

c.) Suggested near future actions.

1.) corrosion control maintenance procedures

2.) modeling and environmental mapping to avoid corrosion prone areas of deployment based on mission requirements

3.) development of corrosion resistant materials

d.) Agencies.

1.) problems are essentially internal to military

2.) but applicable to entire aerospace industry, especially if acid rain gets worse

3.) efforts should be shared rather than duplicated

II. Introduction. Acid Rain.

Operations in an increasingly corrosive environment requires a systematic approach to protecting aircraft and aircraft components from such naturally and man-made occurrences as:

1.) proximity to oceans (Cl^- in air)

2.) humidity

3.) sun angle and incoming solar radiation

4.) acid rain

5.) temperature

6.) other cumulative effects

One approach is a prescribed schedule of washing, repainting, and corrosion control maintenance based on aircraft deployment.

III. Current Status.

a.) Operational procedures.

1.) periodically wash, repaint (camouflage), perform corrosion control maintenance.

2.) is function of deployed location based on suspended particulates, acid rain, Cl^-, humidity, precipitation, sunlight.

b.) Training

1.) once maintenance schedule is established, teach operation/users to be on lookout for corrosion.

c.) R&D

1.) develop coating materials (paints) which prolong repaint cycle and eliminate frequent washings.

d.) Data base and retrieval

1.) expand acid rain, Cl^-, suspended particulate data gathering, reporting network.

e.) Forecasting and dissemination of weather information N/A. Problem is climatological.

f.) Development and dissemination of models and design criteria

1.) improved modeling of dispersion of Cl^- and suspended particulates.

IV. Deficiencies and Voids in Current System

a.) Weaknesses in procedures/system design

1.) use of ferrous metals in remote A/C points hard to reach and susceptible to corrosion.

2.) adhesives used compositer susceptible to some of same meteorological parameters that cause corrosion: humidity, temperature

3.) need easily cleanable/washable A/C bilge where water cannot collect.

4.) area around urinals on AF A/C corrode very rapidly.

b.) See above.

V. Ongoing Research

a.) Expansion of acid rain MAPS3 meaning network and including suspended particulate measurements.

b.) R&D into corrosion resistant paints at least for camouflaged AF A/C.

c.) As current answer: repaint, wash, corrosion control maintenance for AF A/C. Periodic, based on deployment.

d.) Corrosion Severity Index

1.) based on corrosive/degradation meteorological/geophysical parameters.

2.) specific for 184 DoD installations worldwide.

3.) uses weighted environmental decision trees.

VI. New and Future Programs

a.) Needs

1.) corrosion-resistant materials

2.) corrosion-control maintenance procedures

3.) modeling or environmental mapping to avoid corrosoin prone deployment based on mission requirements.

b.) Order of importance (from a. above)
2)
3)
1)

c.) Responsible Agencies

1.) internal to the AF

2.) but applicable to entire aerospace industry

3.) efforts should not be duplicated, rather shared

d.) Development time and interim measures

1.) the wash, repaint, maintenance approach is a long-term interim measure requested by AF Logistics Command. The major command tasked with AF maintenance.

2.) modeling. On-going and under continued revision and refining.

3.) corrosion resistant coatings. On-going and under revision and refining.

Heavy Rain Effects on Aircraft Report

James K. Luers, University of Dayton (co-chairman)

Heavy rain may have been a serious factor in several thunderstorm related accidents attributed to wind shear. A theoretical study conducted by the University of Dayton Research Institute (UDRI) indicates that the roughening of an airfoil that may occur when an aircraft penetrates a heavy rain cell could produce serious drag and lift penalties. The lift penalty is believed most severe at high angles of attack. A decrease in maximum lift of 30 percent or more and a decrease in the stall angle from one to six degrees may result. This lift penalty may have been a serious factor in several accidents/incidents in which a go-around maneuver was being executed. A drag penalty in the range of five to thirty percent, depending on the intensity of the rain, may also exist at all angles of attack. The increased drag would slow the aircraft, causing it to descend below the glide slope and increase its descent rate. The drag penalty may have been a significant factor in several accidents where the aircraft impacted short of the runway threshold.

The results of the UDRI theoretical analysis are presently not validated. Before any conclusive statements can be made concerning the effects of heavy rain on aircraft, further research and model validation is necessary. Because of the importance of this topic and its potential influence on aviation safety, the committee strongly recommends a continued and expanded research program in this area.

Specific research recommendations by priority are as follows.

1.) Establish lift penalty in heavy rain, especially at high angle of attack.

Wind tunnel and/or flight tests should be pursued to establish the relationship between high lift curve of a smooth airfoil and that of an airfoil experiencing heavy rain. The tests should include airfoils with the lift devices typically used by transport aircraft in the landing and go-around configuration. If rain effects can be properly scaled, wind tunnel tests could provide the needed results. If not, flight tests may be needed in a heavy rain environment using a panel of the airfoil that has been roughened in a manner that simulates the rain roughness.

2.) Establish drag penalties due to heavy rain.

Wind tunnel and/or flight tests should be performed to establish the drag and momentum penalty that may be produced by an aircraft penetrating heavy rain. If possible the drag penalty should also be established at all angles of attack. It may be possible to simulate the rain environment on a full chord airfoil segment in a wind tunnel at low angles of attack. Further wind tunnel tests could then be performed with a scale model at other angles of attack using the full-size model as a benchmark test case. Airfoils with high lift devices should be included in the tests.

3.) Define the heavy rain/wind shear/visibility environment of a thunderstorm.

Horizontal wind shear, vertical wind shear, heavy rain, and visibility all affect the performance and capability of an aircraft in the landing configuration. All of these factors are associated with the thunderstorm environment. A better definition of the correlation between these parameters in the thunderstorm environment is required. The JAWS Program may provide the data necessary for this correlation study if it can be extended to include the necessary measurements of rainfall rates and visibility in addition to wind shear observations that are planned. It is recommended that a correlation study be pursued.

4.) Accident reconstruction.

Further analysis and landing simulations are justified on previous accidents in which heavy rain may have been a significant parameter. However, any extensive research program should await the completion of the research task that established the magnitude in lift and drag penalties associated with heavy rain.

5.) Introduce heavy rain effects into aircraft simulators.

If heavy rain is shown to produce significant lift, drag, and momentum penalties, then these effects should be included into aircraft flight simulators. However, the research necessary to model these effects must await the establishment of the magnitude of lift, drag, and momentum penalties associated with heavy rain.

SECTION VIII
CONCLUDING REMARKS

CONCLUDING REMARKS

John Blasic

National Oceanic and Atmospheric Administration

It was certainly an honor to be here with such an expert group of participants, and the National Oceanic and Atmospheric Administration (NOAA) certainly thinks there is a lot to be gained from this interchange among all the disciplines that we have represented here. With all the recommendations that are coming out of this workshop, we certainly have our work cut out for us for a long time to come. I'd like to thank everybody for attending in light of the travel restrictions that we had placed upon us. I certainly hope that we can continue this workshop on an annual basis, although in light of budget restrictions there may be recommendations that it not be held as frequently. Thank you for your interest in aviation efficiency and safety.

Joseph F. Sowar

Federal Aviation Administration, NEXRAD

On behalf of the Federal Aviation Administration (FAA), I would like to offer our appreciation for the effort people have made in coming down here and digging into these problems. They are problems for all of our organizations. This time I hope we get the results of the workshop to higher management a little better than we have in the past. I expect that this year our programs are going to tackle your problems in probably a little more positive way than in the past. Thanks again for coming.

A. Richard Tobiason

NASA Headquarters

I think you always have mixed emotions about these séances, but the closer I get to these things, the more expectation I have of them. I think the idea of interaction is superb. It leads to synergism, and I think we should get more bang from the dollar by this form of communication. We've reacted real strongly this year to Frank Van Demark's comments on the use of recommendations, but we should not overlook the whole idea of why we are here. One of the major ideas why we are here is to transfer knowledge. Who is doing that? Rudy Beavin comes down and talks about his advanced development plan in atmospheric electricity, and that kind of dispells the notion of a national flying laboratory. It tells me that our recommendations aren't always that solid, and that they need to be reviewed all the time.

I've heard at least fifteen recommendations that were very similar to those made last year. So, we really ought to do a better job of screening last year's recommendations. I think we have got to do a better job of following up. The committee structure has to have more members who are principals to getting the job done that can feed back what has happened since last year so that timely recommendations can be provided.

There has been a very simple theme that has come out of this workshop, the idea of real-time utilization of common data bases and sharing hazardous information. Everybody is worried about pacing and getting things done quicker, and that is because people aren't making money out there. We've probably concentrated on the airlines at the expense of other operators in the system. We've got to get the other people involved here. Next year, Gary Livack intends to have more of the GAMA people involved.

On the bright side, a lot of things that you have said have influenced what we will do in NASA. You might say that we in NASA developed a road map of how to resolve the heavy rain fall problem while we were here. Joe Stickle, Jim Luers, and a few other people sat down off to one side, and we worked that problem a little more than we had before we got here. It does have an influence on all of us day to day, and we appreciate it, and we thank you for coming, especially those of you who had to pay your own way here. That shows dedication, and we appreciate it. I don't think the communication stops here. I hope you have exchanged phone numbers so you can follow up in your own particular area that which is important to you and with the people doing the job. Thank you very much.

John W. Connolly

University of Tennessee Space Institute

In the past years when I stood up here, I always knew who I was because I represented the National Oceanic and Atmospheric Administration (NOAA). It is a little bit different now. This is my first time to represent the University of Tennessee Space Institute (UTSI). I would like to take first a slight exception to what Frank Van Demark said in his memo and then highly endorse another part. I don't agree, and I have a feeling that Frank didn't mean it this way, but we spend a little bit too much time on getting this participation from such a wide variety of disciplines that we don't spend enough time on getting the recommendations to higher management. I'm all in favor of even broadening the participation to look for other disciplines that are involved in the aviation community that we haven't yet tapped. At the same time, I do think we've got to get the recommendations to higher management. I'd like to broaden that a little bit. I think those of us who either don't represent government or no longer represent it, might find it useful to bring these recommendations to our top management. I think there is an area there that might be quite useful if we were to ensure that middle and top management in the non-government organizations knew about these workshops and knew about the recommendations, it might be to our mutual advantage. Thank you.

Dennis W. Camp

NASA/Marshall Space Flight Center

I'll just make a standard comment that I generally make at the workshop. The workshop could not exist were it not for the participants, the members that attend, the chairmen, and the speakers. It is not the Organizational Committee that makes the workshop what it is, and any success that we have is directly back to you people that have discussed; you've argued; you've batted heads; call it what you like. That is what makes this a workshop, and that is where the value of the workshop comes from. I sincerely appreciate it, and I appreciate you, and if you have a bad comment to make about it, make it to us, and if you have a good comment to make about it, spread it among your cohorts back at work or wherever and let's see if we can't get a broader base of people as Jack just mentioned. Thank you again, and I look forward to seeing you in the future.

Walter Frost

University of Tennessee Space Institute

That brings us to a close, and I had asked Pam to be down here so I could once again have the opportunity for you to express your appreciation to her for all the work she has done. However, she is not here, even though I am her hoss and asked her to come down. I have a slogan here at UTSI, "There they go; I must hasten after them for I am their leader". So with that, I thank you all for coming, and I know it has been hard to get travel money. We really appreciate it, and we hope to see you next year.

APPENDICES

APPENDIX A

ACRONYMS

ACAR	ARINC COMMUNICATIONS ADDRESSING AND REPORTING SYSTEM
ADP	ADVANCED DEVELOPMENT PROGRAM
ADAP	AIRPORT DEVELOPMENT AID PROGRAM
AEH	ATMOSPHERIC ELECTRICITY HAZARDS
AEHP	ATMOSPHERIC ELECTRICITY HAZARDS PROTECTION
AFGL	AIR FORCE GEOPHYSICAL LABORATORY
AFOS	AUTOMATION OF FIELD OPERATIONS AND SERVICES
AFWAL	AIR FORCE WRIGHT PATTERSON AERONAUTICAL LABORATORIES
AIRMET	AIRMAN'S METEOROLOGICAL INFORMATIO.
ALPA	AIRLINE PILOTS ASSOCIATION
ALWOS	AUTOMATIC LOW-COST WEATHER OBSERVING SYSTEM
AMDAR	AIRCRAFT METEOROLOGICAL DATA RELAY
AOPA	AIRCRAFT OWNERS AND PILOTS ASSOCIATION
APU	AUXILIARY POWER UNIT
ARF	AVIATION ROUTE FORECAST
ARINC	AERONAUTICAL RADIO INCORPORATED COMMUNICATIONS SYSTEM
ARTCC	AIR ROUTE TRAFFIC CONTROL CENTER
ASDAR	AIRCRAFT/SATELLITE DATA RELAY
ATC	AIR TRAFFIC CONTROL
ATIS	AUTOMATIC TERMINAL INFORMATION SERVICE
AWOS	AUTOMATED WEATHER OBSERVATION SYSTEM
BFG	B.F. GOODRICH
CAT	CLEAR AIR TURBULENCE
CDC	CONTROL DATA CORPORATION
CG ATIS	COMPUTER GENERATED AUTOMATIC TERMINAL INFORMATION SERVICE
CGI	COMPUTER GENERATED IMAGERY
CHI	CLOUD HEIGHT INDICATOR
CONUS	CONTINENTAL UNITED STATES
CRT	CATHODE RAY TUBE
CSU	COLORADO STATE UNIVERSITY
CWA	CENTER WEATHER ADVISORY
CWSU	CENTER WEATHER SERVICE UNIT
DABS	DISCRETE ADDRESS BEACON SYSTEM
DABS DL	DISCRETE ADDRESS BEACON SYSTEM DATA LINK
DNA	DEFENSE NUCLEAR AGENCY
DOC	DEPARTMENT OF COMMERCE
DOD	DEPARTMENT OF DEFENSE
DOE	DEPARTMENT OF ENERGY
DOT	DEPARTMENT OF TRANSPORTATION
DSD	DROP SIZE DISTRIBUTION
DUAT	DIRECT USER ACCESS TERMINAL
EDF	EXPLORATORY DEVELOPMENT FACILITY
EFAS	ENROUTE FLIGHT ADVISORY SERVICE
EPA	ENVIRONMENTAL PROTECTION AGENCY
ERL	ENVIRONMENTAL RESEARCH LABORATORY
ETABS	ELECTRONIC TABULATOR DISPLAY SYSTEM
EWEDS	ENROUTE WEATHER DISPLAY SYSTEM
FAA	FEDERAL AVIATION ADMINISTRATION
FAR	FEDERAL AVIATION REGULATION
FL	FLIGHT LEVEL
FSAS	FLIGHT SERVICE AUTOMATION SYSTEM
FSDPS	FLIGHT SERVICE DATA PROCESSING SYSTEMS
FSS	FLIGHT SERVICE STATION
GAMA	GENERAL AVIATION MANUFACTURER ASSOCIATION
GASP	GLOBAL AIR SAMPLING PROGRAM
GE	GENERAL ELECTRIC
GOES	GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE
HISS	HELICOPTER ICING SPRAY SYSTEM
HUD	HEADS-UP-DISPLAY
IAS	INDICATED AIR SPEED
ICAO	INTERNATIONAL CIVIL AVIATION ORGANIZATION
IFR	INSTRUMENT FLIGHT RULES
ILS	INSTRUMENT LANDING SYSTEM

INS	INERTIAL NAVIGATION SYSTEM
IRT	ICING RESEARCH WIND TUNNEL
IVRS	INTERIM VOICE RESPONSE SYSTEM
JAWOS	JOINT AVIATION WEATHER OBSERVATION SYSTEM
JAWS	JOINT AIRPORT WEATHER STUDIES PROJECT
JFK	JOHN F. KENNEDY AIRPORT
JPL	JET PROPULSION LABORATORY
JSPO	JOINT SYSTEMS PROGRAM OFFICE
L/D	LIFT-TO-DRAG
LFM	LIMITED AREA FIVE MESH
LLWS	LOW-LEVEL WIND SHEAR
LSA	LEASED SERVICE A
LWC	LIQUID WATER CONTENT
MCIDAS	MAN-COMPUTER INTERACTIVE DATA ACCESS SYSTEM
MDA	MINIMUM DECISION ALTITUDE
MSFC	MARSHALL SPACE FLIGHT CENTER
MSL	MEAN SEA LEVEL
MVD	MEAN VOLUME DIAMETERS
NACA	NATIONAL ADVISORY COMMITTEE ON AERONAUTICS
NADIN	NATIONAL AIRSPACE DIGITAL INFORMATION NETWORK
NAS	NATIONAL AIRSPACE SYSTEM
NASA	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NAVAIDS	NAVIGATIONAL AIDS
NB	NANOBARS
NCAR	NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
NEXRAD	NEXT GENERATION WEATHER RADAR
NMC	NATIONAL METEOROLOGICAL CENTER
NOAA	NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOTAM	NOTICE TO AIRMEN
NPRM	NOTICE OF PROPOSED RULE-MAKING
NRL	NAVAL RESEARCH LABORATORY
NSF	NATIONAL SCIENCE FOUNDATION
NSSL	NATIONAL SEVERE STORMS LABORATORY
NTSB	NATIONAL TRANSPORTATION SAFETY BOARD
NWS	NATIONAL WEATHER SERVICE
OAT	OUTSIDE AIR TEMPERATUPE
OWRM	OFFICE OF WEATHER RESEARCH AND MODIFICATION
PATWAS	PILOT AUTOMATIC TELEPHONE WEATHER ANSWERING SERVICE
PDP	PROGRAM DEVELOPMENT PLAN
PIREP	PILOT REPORT
PIRM	PRESSURE ICE RATE METER
PMS	PARTICLE MEASURING SYSTEMS
PROFS	PROTOTYPE REGIONAL OBSERVATION AND FORECAST SYSTEM
PSBT	PILOT SELF BRIEFING TERMINAL
PVD	PLAN VIEW DISPLAY
R&D	RESEARCH AND DEVELOPMENT
R&T	RESEARCH AND TECHNOLOGY
RVR	RUNWAY VISUAL RANGE
SERI	SOLAR ENERGY RESEARCH INSTITUTE
SIGMETS	SIGNIFICANT METEOROLOGICAL ADVISORY
SST	SUPERSONIC TRANSPORT
SVR	SLANT VISUAL RANGE
TAS	TRUE AIR SPEED
TCV	TERMINAL CONFIGURED VEHICLE
TIDS	TERMINAL INFORMATION DISPLAY SYSTEM
TKS	TKS, LIMITED (UNITED KINGDOM)
TOMS	TOTAL OZONE MAPPING SPECTROMETER
TRACON	TERMINAL RADAR APPROACH CONTROL FACILITY
TWEB	TRANSCRIBED WEATHER BROADCAST
UDRI	UNIVERSITY OF DAYTON RESEARCH INSTITUTE
USAF	UNITED STATES AIR FORCE
UTSI	UNIVERSITY OF TENNESSEE SPACE INSTITUTE
VAS	VISSR ATMOSPHERIC SOUNDER
VFR	VISUAL FLIGHT RULES
VHF	VERY HIGH FREQUENCY

VISSR	VISIBLE AND INFRARED SPIN SCAN RADIOMETER
VMC	VISUAL METEOROLOGICAL CONDITIONS
VOR	VHF OMNIDIRECTIONAL RADIO RANGE
VRS	VOICE RESPONSE SYSTEM
WAVE	WIND, ALTIMETER, AND VOICE EQUIPMENT
WBRR	WEATHER BUREAU REMOTE RADAR
WFC	WALLOPS FLIGHT CENTER
WMO	WORLD METEOROLOGICAL ORGANIZATION
WPAFB	WRIGHT PATTERSON AIR FORCE BASE
WPL	WAVE PROPAGATION LABORATORY
WSFO	WEATHER SERVICE FORECAST OFFICE

APPENDIX B

FIFTH ANNUAL WORKSHOP ON
METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

Roster of Workshop Participants

Name	Address	Phone Number
James R. Banks	Consultant, Airspace and Air Traffic Control HQ Air Force Communications Command DCS/Air Traffic Services Scott AFB, IL 62225	(618)256-3174 FTS 255-3174 AV 638-3174
Neal M. Barr	Meteorologist Boeing Commercial Airplane Company PO Box 3707 ORGN. B-8404, MS 73-07 Seattle, WA 98124	(206)237-8113
Rudy Beavin	Engineer AFWAL-Flight Dynamics Laboratory AFWAL/FIEA Wright Patterson AFB, OH 45433	(513)255-2395
Arthur D. Belmont	Director, Meteorology Research Control Data Corporation Box 1249C Minneapolis, MN 55440	(612)853-3595
John Blasic	NWS Representative to FAA DOC/NOAA/NWS 800 Independence Avenue, SW Washington, DC 20591	(202)426-3403
John H. Bliss	Flying Tiger Line 2740 Graysby Avenue San Pedro, CA 90732	(213)831-1813
Michael J. Bliss	Free Lance Flight Instructor 2740 Graysby Avenue San Pedro, CA 90732	(213)831-1813
Ronald R. Brown	Commander, Detachment 1, 2nd Weather Squadron USAF-Aeronautical Systems Division/WE Wright Patterson AFB, OH 45433	(513)225-2207
Dennis W. Camp	Aerospace Engineer Atmospheric Science Division ES82 NASA/Marshall Space Flight Center AL 35812	(205)453-2987
Warren Campbell	Aerospace Engineer Atmospheric Science Division ES82 NASA/Marshall Space Flight Center AL 35812	(205)453-1886
Fernando Caracena	Physicist Department of Commerce/NOAA NOAA/ERL, R31 Boulder, CO 80303	(303)497-6269
Robert E. Carr	Supervisory Physicist NASA/Wallops Flight Center Wallops Island, VA 23337	(804)824-3411 x488
Raoul Castro	Flight Safety Foundation 5510 Columbia Pike Arlington, VA 22204	(312)665-3334

Name	Address	Phone Number
Harry W. Chambers	Aerospace Engineer U. S. Army Aviation Research and Development Command 4300 Goodfellow Drive St. Louis, MO 63122	(314)263-1708
Rick Clarke	Manager, Flight Operational Safety Flight Safety Foundation 5510 Columbia Pike Arlington, VA 22204	(703)820-2777
Herb J. Coffman	Project Engineer Bell Helicopter Textron PO Box 482 Ft. Worth, TX 76101	(817)280-3231
Frank Collins	Associate Professor University of Tennessee Space Institute Tullahoma, TN 37388	(615)455-0631 x459
John W. Connolly	Director, Government Operations Alden Electronics Westborough, MA 01581	(703)765-1948
Don S. Cornwall	Air Line Pilots Association Airworthiness and Performance Committee 2006 East Mary's Creek Pearland, TX 77581	(713)485-1095
J. Charles Derrick, Jr.	Manager, Control Center Federal Express Corporation PO Box 727, Department 133 Memphis, TN 38194	(901)369-2615
Mark Dietenberger	Assistant Research Physicist University of Dayton Research Institute College Park Avenue Dayton, OH 45469	(513)229-3921
Peggy L. Evanich	Aerospace Engineer NASA/Lewis Research Center 21000 Brookpark Road MS 86-8 Cleveland, OH 44135	(216)433-4000 x6122
George H. Fichtl	Chief, Fluid Dynamics Branch ES8? NASA/Marshall Space Flight Center AL 35812	(205)453-0875
Richard L. Foss	Chief Engineer, Advance Design Lockheed California Company Department 75-01, Bldg. 63 Burbank, CA 91520	(213)847-0875
Sepp Froeschl	Supervisor CPQ Department of Environment - A.E.S. Canada 100 Alexis Nihon Ville St. Laurent Quebec, Canada H9P 1X5	(514)333-3070
Walter Frost	Director, Atmospheric Science Division University of Tennessee Space Institute Tullahoma, TN 37388	(615)455-0631 x217

Name	Address	Phone Number
Dagfinn Gangsaas	Specialist Engineer Boeing Commercial Airplane Company Box 3707 Seattle, WA 98124	(206)773-5300
Joel M. Graybeal	Research Assistant University of Maryland Flight Research Group Wind Tunnel Operations College Park, MD 20742	(301)454-4309
Gordon O. Handberg	Manager, Simulation Manager McDonnell Douglas Electronics Company PO Box 426 St. Charles, MO 63301	(314)925-4467
Wayne Higginbotham	125 Westbury Drive Huntsville, AL 35802	
John W. Hinkelman, Jr.	FAA Representative to PROFS Program FAA Environmental Research Labs, NOAA Boulder, CO 80303	(303)497-6819
John C. Houbolt	Chief Aeronautical Scientist NASA/Langley Research Center MS 249 Hampton, VA 23665	(804)827-3216
Richard K. Jeck	Research Associate Professor in Meteorology U. S. Naval Academy Code 4323 Annapolis, MD 21402	(202)767-2437 AV 297-2437
Joe R. Kelley	Manager, Forecast Services Department Global Weather Dynamics, Inc. 2400 Garden Road Monterey, CA 93940	(408)649-4500
John T. Klehr	Meteorologist/Systems Engineer Link Division, Singer Corporation Department 517-H Binghamton, NY 13902	(607)772-4273
Prem Kumar	Research Associate FWG Associates, Inc. Park Plaza 1132 303 William Avenue Huntsville, AL 35801	(205)533-7590
Kirk E. Lehneis	Assistant Chief, Forecasting Services Division Headquarters Air Weather Squadron HQAWS/DNTS Scott AFB, IL 62269	(618)256-4741 FTS 255-4741
Gary S. Livack	Manager, Technical Activities GAMA Suite 517 1025 Connecticut Avenue, NW Washington, DC 20036	(202)206-8111
George A. Lucchi	Manager, Advanced Avionics Sperry Flight Systems 8500 Balboa Blvd. Van Nuys, CA 91409	(213)894-8111

Name	Address	Phone Number
James K. Luers	Senior Research Scientist University of Dayton Research Institute College Park Avenue Dayton, OH 45469	(513)229-3921
Charles A. Lundquist	Director, Space Sciences Laboratory ES81 NASA/Marshall Space Flight Center AL 35812	(205)453-3105
John McCarthy	Staff Scientist National Center for Atmospheric Research PO Box 3000 Boulder, CO 80307	(303)497-0651
William W. Melvin	Chairman, Airworthiness and Performance Committee Air Line Pilots Association 1101 W. Morton Denison, TX 75020	(214)463-1246
Dennis W. Newton	Chief, Engineering Test Pilot LearFan Corporation (U.S.) PO Box 60000 Reno, NV 89506	(702)972-2675
Porter J. Perkins	Aerospace Engineer NASA/Lewis Research Center MS 86-1 21000 Brookpark Road Cleveland, OH 44135	(216)433-4000 x5535
Byron B. Phillips	Manager, Research Aviation Facility National Center for Atmospheric Research PO Box 3000 Boulder, CO 80307	(303)494-5151 x7850
John Prodan	President AV-CON 1100 Kings Road Rapid City, SD 57701	(605)348-9329
William A. R. Robertson	Air Line Pilots Association Air Worthiness and Performance Committee 239 Wellington Drive Crystal Lake, IL 60014	(815)459-6219
Robert J. Roche	Aviation Weather Program Manager Systems Research and Development Service FAA 400 7th Street, SW Washington, DC 20591	(202)426-9194
Gregory D. Salottolo	Meteorologist National Transportation Safety Board 800 Independence Avenue, SW Washington, DC 20594	(202)472-6096
Charles F. Schafer	Physicist ES82 NASA/Marshall Space Flight Center AL 35812	(205)453-1886
Ron Sessa	Vice President of Flying USAir Greater Pittsburgh International Airport Pittsburgh, PA 15231	(412)777-7097

Name	Address	Phone Number
Robert E. Smith	ES81 NASA/Marshall Space Flight Center AL 35812	(205)453-3101
Joseph F. Sowar	Deputy Director, NEXRAD FAA NEXRAD JSPO WX7 8060 13th Street Silver Spring, MD 20910	(301)427-7150
Peter W. Speck	Staff Meteorologist AFWAL Flight Dynamics Laboratory AFWAL/WEF Wright Patterson AFB, OH 45433	(513)255-5019
Joseph W. Stickle	Chief, Flight Mechanics Division NASA/Langley Research Center MS 246A Hampton, VA 23665	(804)827-2037
James F. Sullivan	Supervisor, Weather USAir Greater Pittsburgh International Airport Pittsburgh, PA 15231	(412)777-7172
Frank B. Tatom	President Engineering Analysis, Inc. 2109 Clinton Avenue, W Suite 432 Huntsville, AL 35805	(205)533-9391
Carl Terry	Staff Engineer United Air Lines Flight Training Center Stapleton International Airport Denver, CO 80207	(303)298-4237
Allan R. Tobiason	Manager, Aviation Safety Technology NASA Headquarters RJT-2 Washington, DC 20546	(202)755-3003 FTS 755-3003
Barry Turkel	Aviation Systems Specialist FWG Associates, Inc. RR2, Box 271-A Lakewood Drive Tullahoma, TN 37388	(615)455-1982
Frank E. Van Demark	Chief, Systems Development Division Systems Research and Development FAA 400 7th Street, SW Washington, DC 20591	(202)426-0024
Richard Van Gemert	Manager, Travel Services Xerox Corporation Hangar G, Westchester Airport White Plains, NY 10604	(914)428-0800
Otha H. Vaughan, Jr.	Space Scientist ES83 NASA/Marshall Space Flight Center AL 35812	(205)453-5218
William W. Vaughan	Chief, Atmospheric Sciences Division ES81 NASA/Marshall Space Flight Center AL 35812	(205)453-3100

Name	Address	Phone Number
S. T. Wang	Research Engineer FWG Associates, Inc. RR2, Box 271-A Lakewood Drive Tullahoma, TN 37388	(615)455-1982
Edwin A. Weaver	Optics Engineer EC32 NASA/Marshall Space Flight Center AL 35812	(205)453-1597
Solomon Weiss	Consulting Engineer 1955 Camberly Drive Lyndhurst, OH 44124	(216)449-2481
G. A. White, III	Staff Meteorologist AFWAL/WEM Wright Patterson AFB, OH 45433	(513)255-6472
Grady W. Wilson	Director of Flight Test U. S. Army Aviation Engineering Flight Activity Edwards AFB, CA 93523	(805)277-4992 or 4993
C. Dennis Wright	Director, Airspace Technology Department Aircraft Owners and Pilots Association PO Box 5800 Washington, DC 20014	(301)951-3921
Andy D. Yates, Jr.	Captain Air Line Pilots Association 7413 Park Terrace Drive Alexandria, VA 22307	(703)765-7423

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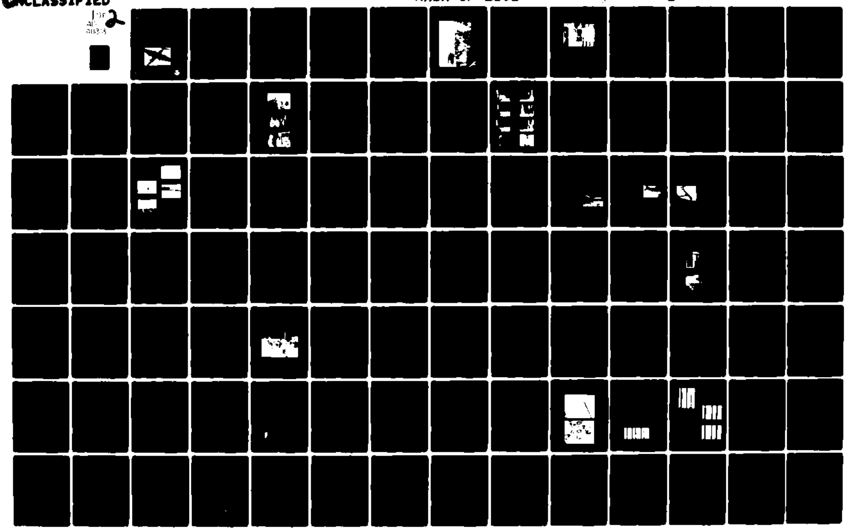

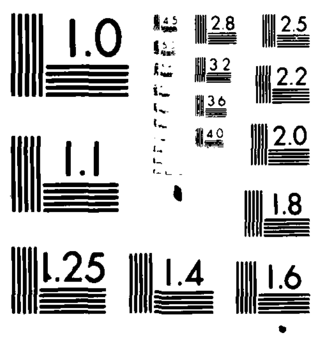
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PROCEEDINGS: FIFTH ANNUAL WORKSHOP ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

MARCH 31 - APRIL 2, 1981

UNIVERSITY OF TENNESSEE SPACE INSTITUTE

EDITORS: DENNIS W. CAMP
WALTER FROST

TECHNICAL EDITOR: PAMELA D. PARSLEY

U.S. Department of Transportation

NOAA
U.S. DEPARTMENT OF COMMERCE · NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

APPROVAL

PROCEEDINGS: FIFTH ANNUAL WORKSHOP ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

Edited by Dennis W. Camp and Walter Frost

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

William C. Snoddy

for J. E. KINGSBURY
Acting Director, Space Sciences Laboratory

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* NASA/Marshall Space Flight Center, Alabama 35812

** UTSI, Tullahoma, Tennessee 37388

16. ABSTRACT

The proceedings of a workshop on meteorological and environmental inputs to aviation systems held at The University of Tennessee Space Institute, Tullahoma, Tennessee, March 30 - April 1, 1981, are reported. The workshop, jointly sponsored by NASA, NOAA, and FAA, brought together many disciplines of the aviation communities in round table discussions. The major objectives of the workshop are to satisfy such needs of the sponsoring agencies as the expansion of our understanding and knowledge of the interaction of the atmosphere with aviation systems, the better definition and implementation of services to operators, and the collection and interpretation of data for establishing operational criteria relating the total meteorological inputs from the atmospheric sciences to the needs of aviation communities. The unique aspects of the workshop were the diversity of the participants and the achievement of communication across the interface of the boundaries between pilots, meteorologists, training personnel, accident investigators, traffic controllers, flight operation personnel from military, civil, general aviation, and commercial interests alike. Representatives were in attendance from government, airlines, private agencies, aircraft manufacturers, Department of Defense, industries, research institutes, and universities.

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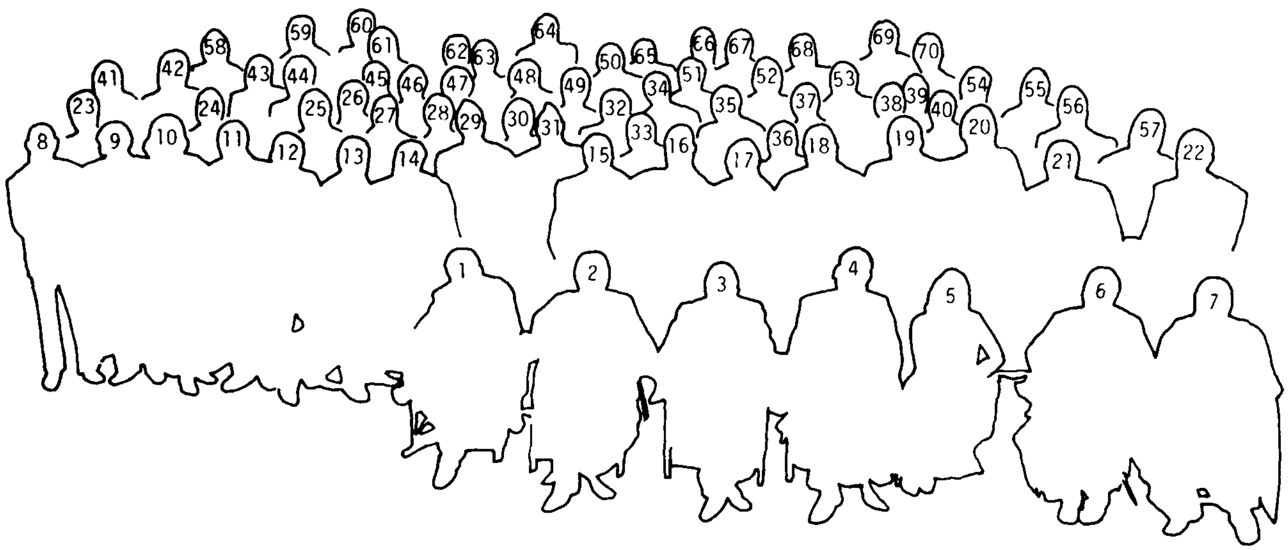

1. Jim Banks
2. Walter Frost
3. Joe Sowar
4. Dennis Camp
5. Pam Parsley
6. Dick Tobiason
7. John Blasic
8. Andy Yates
9. Barry Turkel
10. Peggy Evanich
11. Robert Carr
12. John Connolly
13. S.T. Wang
14. Prem Kumar
15. Sepp Froeschl
16. Frank Tatom
17. Warren Campbell
18. John Hinkelman
19. Joe Stickle
20. Dagfinn Gangsaas
21. Andy White
22. George Lucchi
23. Charles Schafer
24. John Prodan
25. William Vaughan
26. Dennis Newton
27. Sol Weiss
28. Frank Collins
29. Kirk Lehneis
30. Pete Speck
31. Ronald Brown
32. Geroge Fichtl
33. Art Belmont
34. Jim Luers
35. Rick Clarke
36. Otha Vaughan
37. Frank Van Demark
38. Joe Kelley
39. Charles Lundquist
40. James Sullivan
41. Jules Bernard
42. John McCarthy
43. Gordon Handberg
44. Neal Barr
45. Raoul Castro
46. Mark Dietenberger
47. Joel Graybeal
48. Byron Phillips
49. Dennis Wright
50. Grady Wilson
51. Robbie Robertson
52. Harry Chambers
53. John Houbolt
54. John Klehr
55. Ed Weaver
56. Charles Derrick
57. Richard Foss
58. Don Cornwall
59. John Bliss
60. Michael Bliss
61. Herb Coffman
62. Carl Terry
63. Richard Jeck
64. Wayne Higginbotham
65. Robert Smith
66. Greg Salottolo
67. Robert Roche
68. Fernando Caracena
69. Porter Perkins
70. Bill Melvin

SECTION I
EXECUTIVE SUMMARY

MEMBERS OF THE ORGANIZATION COMMITTEE
(FROM LEFT TO RIGHT)

WALTER FROST, UTSI
JOHN W. CONNOLLY, UTSI
JOSEPH I. SOWAR, FAA
PAMELA D. PARSLEY, UTSI
JOHN BLASIC, NWS
DENNIS W. CAMP, NASA/MSFC
A. RICHARD TOBIASON, NASA HDQ.
EDWARD M. GROSS, NOAA (Not Pictured)

EXECUTIVE SUMMARY: FIFTH ANNUAL WORKSHOP ON METEOROLOGICAL AND ENVIRONMENTAL INPUTS TO AVIATION SYSTEMS

Dennis W. Camp, Walter Frost,

Edward M. Gross, Joseph F. Sowar, and Allan R. Tobiason

Organization Committee

Introduction

Annual workshops concerned with meteorological and environmental inputs to aviation systems have been jointly sponsored by the NASA, NOAA, and FAA and hosted by the University of Tennessee Space Institute (UTSI). The purpose of these workshops is two-fold. Namely, to bring together various disciplines of the aviation community with meteorologists and atmospheric scientists in interactive discussions in an effort to establish and identify the weather needs of the community and how these needs might be satisfied. This purpose is considered to be one of the main features of the workshops. Secondly, these needs are used to develop recommendations which are then used to structure the relative programs of the sponsoring agencies in order to enhance aviation safety and efficiency. Results from these workshops have been published in proceedings (Camp and Frost, 1977, Frost and Camp, 1978, Camp and Frost, 1979, Frost and Camp, 1980, and Camp and Frost, 1980), in the open literature (Frost, Camp, Connolly, Enders, Sowar, and Burton, 1979, Camp, Frost, Connolly, Enders, and Sowar, 1980, and Camp, Frost, Gross, Sowar, and Tobiason, 1980) and presented at conferences (Frost, Camp, Enders, Sowar, and Connolly, 1979 and Camp, Frost, Gross, Sowar, and Tobiason, 1981). Due to the extensive coverage of the first four workshops, this paper will be concerned with a summarization of the fifth workshop which had as its theme "Impact of Meteorology on Future Aviation Efficiency, Operations, Design, and Safety".

An indication of the cross section of the attendees is seen in Table 1. There were 72 people in attendance representing 38 organizations. These attendees were assigned to the ten committes listed in Table 2. Interaction among the committee members was achieved by having the floating committees meet with each of the fixed committees. The floating committees did not meet with each other, neither did the fixed committees meet with each other.

TABLE 1

ATTENDEE REPRESENTATION

GOVERNMENT SECTOR (31)	Foreign (1)
Federal Aviation Administration	Atmospheric Environment Service of Canada
National Aeronautics & Space Administration	
National Oceanic & Atmospheric Administration	Industry (17)
National Transportation Safety Board	
U. S. Air Force	Alden Electronics Co.
U. S. Army	AV-CON Corp.
U. S. Naval Academy	Bell Helicopter Co.
U. S. Naval Research Laboratory	Boeing Co.
	Control Data Corp.
PRIVATE SECTOR (41)	Engineering Analysis, Inc.
	FWG Associates, Inc.
Airlines (5)	Global Weather Dynamics, Inc.
	LearFan Corp.
Federal Express Corp.	Lockheed Corp.
Flying Tiger Line	McDonnell Douglas Co.
United Airline	Singer Corp.
USAir	Sperry Flight Systems
	Xerox Corp.
Associations (8)	
	Private Consultants (3)
Aircraft Owners & Pilots Assn. (AOPA)	
Air Line Pilots Assn. (ALPA)	University and Research (7)
Air Traffic Control Assn. (ATCA)	
Air Transport Assn. (ATA)	National Center for Atmospheric Research
Flight Safety Foundation, Inc. (FSF)	University of Dayton Research Institute
General Aviation Manufactuer Assn. (GAMA)	University of Maryland
	University of Tennessee Space Institute

TABLE 2

1981 WORKSHOP COMMITTEES
AND RESPECTIVE COMMITTEE CHAIRMAN

FIXED COMMITTEES	FLOATING COMMITTEES
Meteorological Inputs to Operational Efficiency	Wind, Wind Shear and Turbulence
Andy D. Yates, Airline Pilots Association	Robert J. Roche, Federal Aviation Administration
Meteorology Input to Advanced Simulators	Icing and Frost
Carl Terry, United Airlines	Harry W. Chambers, U. S. Army
Operational Procedures Relative to Severe Weather	Atmospheric Electricity and Lightning
Fernando Caracena, National Oceanic & Atmospheric Admin.	Charles F. Schafer, NASA/Marshall Space Flight Center
Impact of Meteorology on Future Aircraft Design	Fog, Visibility, and Ceiling
Richard L. Foss, Lockheed, California Company	Byron B. Phillips, National Center for Atmospheric Research
Meteorology Impact on Air Traffic Control Design	Ozone and Other Meteorological and Atmospheric Parameters
James R. Banks, ATC Consultant	Arthur D. Belmont, Control Data Corporation

Objective of Workshop

The major objective of this workshop, as well as the previous four, has been to provide on an annual basis a collective view of aviation weather from the users, suppliers, regulators, researchers, and educators as to (1) specific recommended actions relative to aviation weather needs and the responsible agencies; (2) current status of operational procedures, design criteria, safety regulations, and training techniques; (3) deficiencies and voids in current systems; (4) on-going research and development and; (5) new and future programs. These objectives satisfy the needs of the sponsors relative to knowledge of the interaction of the atmosphere with aeronautical systems, to better define and implement meteorological services, and the collection and interpretation of data for establishing operational criteria relating to the total meteorological inputs from the atmospheric sciences to the operational and educational needs of the aviation community. A collective view is achieved by assuring that representation on the committees is obtained from a wide range of government and private organizations, as noted in Table 1.

Workshop Formal Presentations

In an effort to establish a common base for the committees' efforts and to set the tempo of the working sessions of the committees, the workshop began with a series of invited overview papers as shown in Table 3. These papers reviewed the meteorological impact on aviation operation

TABLE 3

INVITED PRESENTATIONS

"Meteorological Impact on Aviation Fuel Efficiency" by David E. Winer and John E. Wesler, Office of Environment and Energy, Federal Aviation Administration
"Meteorological Inputs to Advanced Simulators" by Gordon O. Handberg, McDonnell Douglas Electronics Company
"Operational Procedures Relative to Severe Weather" by James F. Sullivan, USAir
"Meteorological Impact on Future Aircraft Design" by Joseph W. Stickle and John C. Houbolt, NASA/Langley Research Center
"Meteorological Impact on ATC System Design" by Frank E. Van Demark, Federal Aviation Administration
"Ozone and Aircraft Operations" by Porter J. Perkins, NASA/Lewis Research Center

efficiency, advanced simulators, procedures relative to severe weather, future aircraft design, and air traffic control system design. Because of the interest in ozone expressed by a number of airlines, a special paper on ozone and aircraft operations was presented.

During the course of the workshop, time was allocated for a number of participants to make either an invited or impromptu presentation. Representatives of each of the sponsoring agencies were invited to give a presentation relative to how recommendations from previous workshops have influenced their specific aviation weather programs. The titles of these presentations are the three listed first in Table 4. Listed, also, in Table 4 are the impromptu and invited presentations. The impromptu speakers discussed ongoing or just completed work that affected operations of the aviation community. These presentations also served to stimulate the discussions of the various committees. In addition to the overview papers and impromptu presentations, Ron Sessa, Vice President of Flying, USAir, gave a banquet speech on the current problems associated with maintaining efficient airline operations. Richard Van Gemert, Manager of Travel Services, Xerox Corporation, gave a speech following one of the group dinners on the meteorological impact on corporate aircraft operating costs. During one of the lunch breaks, the Academy Award winning documentary film on "The Flight of the Gossamer Condor" was shown.

Main Workshop Feature

As indicated earlier, one of the main features of the workshops is the interactive committee working sessions. In an effort to enhance the benefits resulting from these interactive sessions, some goals were established. Of major concern to the program is the impact of meteorology on the efficiency of aviation operations, on programming and design of advanced simulators, on operating procedures in hazardous weather, on the design of future aircraft, on the design and operational procedures of the air traffic control (ATC) system. Examples of topics the committees were requested to discuss in order to ensure these major concerns were addressed are given in the following paragraphs.

Under the topic of aviation operation efficiency, major emphasis was placed on fuel economy. How-

TABLE 4

IMPROMPTU PRESENTATIONS

"Review of FAA Status of Recommendations Documented in Previous Workshops" Joseph F. Sowar, NEXRAD, Federal Aviation Administration
"What the NWS is Doing as a Response to the Workshops" John Blasic, National Weather Service, Representative to Federal Aviation Administration
"Status of NASA's Responses to the 1980 Workshop Recommendations" A. Richard Tobiason, NASA Headquarters
"Progress on Low Altitude Cloud Icing Research" Richard K. Jeck, Naval Research Laboratory and Naval Academy
"NASA Lewis Research Center's Icing Research Program" Peggy L. Evanich, NASA/Lewis Research Center
"Effect of Heavy Rain on Aircraft" James K. Luers, University of Dayton Research Institute
"Prototype Regional Observation and Forecast System (PROFS)" John W. Hinkelman, Jr., Federal Aviation Administration, Representative to NOAA/PROFS
"Cabin Ozone and Tropopause Definition" Arthur D. Belmont, Control Data Corporation
"Atmospheric Electricity Hazards Protection" Rudy Beavin, U. S. Air Force
"Joint Airport Weather Studies (JAWS)" John McCarthy, National Center for Atmospheric Research

ever, the much broader area of flight scheduling, dispatching, taxiing, route forecasting, climb trajectory, definition of tropopause and other factors influenced by the weather were discussed. In turn, relative to the aircraft design committee, discussions pertain to gust alleviation, low drag airfoils, composite and bonded structure (i.e., thermal and lightning effects), bleed air availability for deicing, etc., were defined goals. Model development and validation of wind shear and turbulence, visibility, cloud cover, temperature and density gradients, rain, snow, and icing degradation on performance for use in manned flight simulators represent topics of major concern to the flight simulator committee. The operational procedures committee addressed procedures to be utilized when severe or hazardous weather is forecast. Procedures to be taken when wind shear exists in the terminal area, when clear air turbulence is forecast. when completion of mission should be considered paramount, etc. were identified. Finally, relative to the air traffic control committee, the system design and the operational procedures during inclement weather as well as during prevailing extreme meteorological conditions whould be incorporated in future ATC design. Examples are control procedures to be taken when icing is occurring on aircraft in the holding pattern and when the deicing system influences aircrafts performance during approach and takeoff, dissemination of thunderstorm warnings during enroute flight particularly to general aviation, the delivery of urgent weather messages, separation distance due to temperature stratification, etc.

The fixed committees interacted with the floating committees on wind shear and turbulence; icing and frost; lightning and atmospheric electricity; fog, visibility, and ceiling; and ozone and other environmental parameters. The impact of these various weather phenomena on current operational procedures, design criteria, and modeling as it pertains to the fixed committees designated topic areas were clearly identified.

Six areas which served as discussion goals are given below: however, the committees were requested to suggest and discuss others as appropriate. Examples are:

1. Management and implementation of design and operation procedures relative to meteorological and environmental impact.
2. Training for designers, operators, and users.
3. Research and development.
4. Data base and retrieval systems.
5. Forecasting and dissemination of weather information.
6. Development and dissemination of models and design criteria.

The committees were asked to: (1) address the current status of the above topic areas; (2) define deficiencies and voids in these areas; (3) describe what research is presently being carried out to solve the deficiencies and what is the status of this research; and (4) identify what new programs are required to satisfy current and future needs. These needs were to be ordered as to importance. Finally, relative to future needs, the committees were ask to identify what organization, whether they be government, industry, research institute, or others, they believe should be responsible for developing the needed operational procedures, models or design criteria. An estimate was also to be made as to how long it will take to develop the new procedures and what, if any, interim measures are required.

Workshop Recommendations

Recommendations from the fifth workshop have been tabulated and are presented in the following sub-sections. There were approximately 109 recommendations of which the 66 listed are what remain after removing duplicates and combining where appropriate. A perusal of the recommendation in these sections will show the workshop participants were concerned with accuracy of forecasts, training of aviation community personnel relative to meteorology, and development of new equipment and/or systems which make aeronautical operations more efficient and safer. As one can see from the recommendations relative to winds, wind shear and turbulence, the participants were also concerned with some factors that were not directly related to meteorology.

A more indepth discussion of the recommendations from the fifth workshop will be given in the Proceedings of the Fifth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems (Camp and Frost, 19[illegible]).

Wind, Wind Shear, and Turbulence: The following recommendations were made relative to winds, wind shear, and turbulence.

1. There is a critical need to increase the data base for wind and temperature aloft forecasts both from a more frequent updating of the data as well as improved accuracy in the data, and thus, also in the forecasts which are used in flight planning. This will entail the development of rational definitions of short-term variations in intensity and scale length (of turbulence) which will result in more accurate foreasts which should also meet the need to improve numerical forecast modeling requirements relative to winds and temperatures aloft.
2. The development of an on-board system to detect wind induced turbulence should be beneficial to meeting the requirement for an investigation of the subjective evaluation of turbulence "feel" as a function of motion drive algorithms.

3. More frequency reporting of wind shift in the terminal area is needed along with greater accuracy in forecasting.

4. There is a need to investigate the effects of unequal wind components acting across the span of an airfoil.

5. The FAA Simulator Certification Division should monitor the work to be done in conjunction with the JAWS project relative to the effects of wind shear on aircraft performance.

6. Robert Steinberg's ASDAR effort should be utilized as soon as possible, in fact it should be encouraged or demanded as an operational system. This would be especially beneficial for flight planning, specifically where winds are involved.

7. There is an urgent need to review the way pilots are trained to handle wind shear. The present method, as indicated in the current advisory circular, of immediately pulling to stick shaker on encountering wind shear could be a dangerous procedure. It is suggested the curcular be changed to recommend the procedure to hold at whatever airspeed the aircraft is at when the pilot realizes he is encountering a wind shear and apply maximum power, and that he not pull to stick shaker except to flair when encountering ground effect to minimize impact or to land successfully or to effect a go-around.

8. Need to develop a clear non-technical presentation of wind shear which will help to provide improved training for pilots relative to wind shear phenomena. Such training is of particular importance to pilots of high performance, corporate, and commercially used aircraft.

9. Need to develop an ICAO type standard terminology for describing the effects of wind shear on flight performance.

10. The ATC system should be enhanced to provide operational assistance to pilots regarding hazardous weather areas and in view of the envisioned controller workloads generated, perfecting automated transmissions containing this type of information to the cockpit as rapidly and as economically as practicable.

11. In order to improve the detection in real-time of hazardous weather, it is recommended that FAA, NOAA, NWS, and DOD jointly address the problem of fragmental meteorological collection, processing, and dissemination pursuant to developing a system dedicated to making effective use of perishable weather information. Coupled with this would be the need to conduct a cost benefit study relative to the benefits that could be realized through the use of such items as a common winds and temperature aloft data base and the use of automatically reporting by use of automated sensors on aircraft.

12. Develop a "capability for very accurate four to six minute forecasts of wind changes which would require terminal reconfigurations or changing runways.

13. Due to the inadequate detection of clear air turbulence an investigation is needed to determine what has happened to the promising detection systems that have been reported and recommended in previous workshops.

14. Improve the detection and warning of wind shear by developing on-board sensors as well as continuing the development of emerging technology for ground-based sensors.

15. Need to collect true three and four dimensional wind shear data for use in flight simulation programs.

16. Recommend that any systems whether airborne or ground based that can provide advance or immediate alert to pilots and controllers should be pursued.

17. Need to continue the development of Doppler radar technology to detect the wind shear hazard, and that this be continued at an accelerated pace.

18. Need for airplane manufacturers to take into consideration the effect of phenomena such as micro bursts which produce strong periodic longitudinal wind perturbations at the aircraft phugoid frequency.

19. Consideration should be given, by manufacturers, to consider gust alleviation devices on new aircraft to provide a softer ride through turbulence.

20. Need to develop systems to automatically detect hazardous weather phenomena through signature recognition algorithms and automatically data linking alert messages to pilots and air traffic controllers.

Icing and Frost: The following recommendations were made relative to icing and frost.

1. There is a need for greater accuracy in forecasting icing conditions as well as an increase of frequency in reporting the icing conditions.

2. In order to be able to determine icing probability, icing areas, and accretion rates, the development of a liquid water content device is needed. In this development program, consideration should also

be given to an icing accretion indicator.

3. It is recommended that research be conducted into methods of deicing aircraft on the ground using other than water glycol mixtures or other petroleum products.

4. There exists a need for icing models for use in simulating the rate of accumulation and type of ice occurring as a function of atmospheric conditions and flight regime. This can also be of benefit to the conduction of design studies to determine how a simulated capability can be achieved.

5. A need exists for a better definition of areas of potential icing conditions, and for providing an icing criteria without specific qualifications. This type information would be very beneficial to the conduction of studies to determine if quantitative assessment of icing environment would provide better information than current qualitative assessments. If this is accomplished then the recommendation that the inconsistency be cleared up to insure the capability of the FAR's regarding operations in icing conditions and the present definition of severe icing could possibly be met.

6. The need exists to characterize icing information better for the lower altitudes. When this has been accomplished then it will be possible to re-evaluate FAR-25 Appendix C criteria to determine if new design icing criteria can be established for the low altitude.

7. A note should be included in the airman's information manual about possible loss of control of some aircraft due to tail plane icing when the flaps are lowered.

8. There exists a need to accomplish a thorough study of the cloud physics during various icing conditions to define quantitative degrees of icing which include icing due to freezing rain.

9. Need empirical models of the effects of airframe and nacelle icing upon the aerodynamic coefficients and engine parameters.

10. A need exists to obtain a realistic simulation of the effects of ice on rotorcraft and fixed wing aircraft.

11. There is a need to continue the studies and necessary experimentation to develop accurate frost forecasting capabilities.

12. Relative to icing and frost efforts, it is recommended to continue the efforts and to report findings at the workshops.

Lightning and Atmospheric Electricity: The following recommendations were made relative to lightning and atmospheric electricity.

1. There is a need to do research on the effects of lightning strikes on aircraft for a variety of reasons, some are:

   a. Relative to the use of fiber optics for aircraft control circuits.

   b. To be able to simulate the adverse effects of lightning strikes on avionic systems.

   c. To develop lightning strike models.

   d. Relative to the development of on-board instruments to detect lightning strike current path on aircrafts.

   e. Concerning the need to understand the phenomena of lightning and how to protect aircrafts from lightning.

   f. To improve and increase the data base of lightning strikes for use in developing regulations on all aspects of lightning as well as for use in design specifications.

2. On-board detectors are needed for the purpose of lightning avoidance.

3. A need exists to conduct research for correlation between actual conditions and that depicted on radar and storm scopes.

4. There is a need to continue the development efforts relative to the storm scopes.

5. That NWS and FAA analyze and test the usefulness of available lightning data to better define convective storm hazards.

6. Research is needed relative to the application of electric field data to prediction models.

7. Need to investigate the use of satellites and Doppler radar in thunderstorm detection and lightning forecasting.

8. Additional research is needed concerning electric field measurement instrumentation.

Fog, Visibility, and Ceilings: The following recommendations were made relative to fog, visibility, and ceilings.

1. Research should continue and be encouraged in three major areas:

   a. Taxi-way Category III control systems.

   b. Warm fog dispersal systems.

c. Development of Heads-Up-Display airborne microwave or infrared systems which are capable of Category III operations without terminal installations.

2. Greater accuracy and frequency in forecasting and reporting formation and dissipation of fog as well as to how best to characterize the information relative to the fog.

3. There is a need to examine the maintenance procedures for ground-based observations and reporting on the equipment. Further, it is recommended that research be conducted relative to improved low-cost visibility sensors and/or markers.

4. Research should be accelerated in fog prediction specific to the primary fog impacted airports of the nation with the aim of improving, through mesoscale observations and mesoscale forecast models or systems, the accuracy of the three to four hour prediction of terminal conditions.

5. A simplified, automatic weather observing system should be developed and installed at other than primary ILS equipped airports which are without present weather observing capabilities. This system should be capable of reporting altimeter, winds, temperature, ceiling, and runway visibility less than the VFR minimums to an in-flight aircraft and also capable of digital telephone or satellite link interrogation for input to a central data collection system.

6. All major commercial air carriers should evaluate the cost effectiveness and the desirability for full Category III operations within their present and planned 1980 decade operational system.

7. High intensity approach lightning systems should be provided at all airports possessing instrument approach systems.

Ozone and Other Meteorological and Environmental Parameters (Acid Rain, Heavy Rain, and Ozone): The following recommendations were made relative to ozone and other meteorological and environmental parameters.

Acid Rain

1. The characteristics of acid rain relative to geographic areas need to be investigated and documented. This should not be limited only to acid rain but also should include chloride, iodide, and several other ion concentrations.

2. The meteorological aspects of the corrosive effects of acid rain needs to be determined and documented.

Heavy Rain

1. There exists a need to characterize heavy rain relative to concentration and its correlation to the wind speed phenomena known as microburst. This will entail a close working relationship between heavy rain and wind shear investigators.

2. Research efforts need to be accomplished to establish the effects of heavy rain on aircraft dynamics and flight performance.

3. Of immediate importance is the pursuit of model validation especially with respect to wind tunnel, C_{Lmax}, flight testing, accident reconstruction, and postflight accident validation.

4. It is highly suggested that the FAA Simulator Certification Division monitor the JAWS project relative to the effects of heavy rain on aircraft performance, and should this prove to be a significant item, establishment of empirical models for predicting the force and moment effects on any airframe should be accomplished.

Ozone

1. In order to increase the ozone data base, it is recommended that funding and installation of sensors aboard selected aircraft.

2. Need to continue efforts to improve techniques to obtain ozone profiles for enhancing the capability to more accurately forecast and report ozone concentrations to the ATC and airlines for a variety of flight paths.

3. The FAA should investigate the feasibility of sanitizing aircraft pressurized compartments with a conditioned source of air or cost effective alternative to catalytic converters. Coupled with this is a consideration of rule making specifically aimed at cargo aircraft with regard to ozone concentrations.

4. The Ozone problem needs to be more precisely defined relative to arriving at reasonable standards. This will logically be related to ozone distribution and the effect of ozone on people.

5. There is a need relative to developing training programs concerning ozone for involved agencies and airlines.

Non-Meteorological Factors: The following recommendations were made relative to non-meteorological factors.

1. Need representative longitudinal and lateral tire friction coefficient data for the various runway conditions.

2. There is a need for models to simulate the transient effects of antiskid systems.

3. Need to thoroughly examine pilot training programs pursuant to eliminating serious deficiencies that exists in training as it relates to weather.

4. A need exists for training users in the interpretation of data from devices which indicate electrical activity.

5. Determine if new methods or information on flight in icing conditions are required and to prepare necessary training films, seminars, and notices.

6. Need to improve the availability of weather education and instructional material to general aviation pilots through audio and video cassettes, scheduled seminars, public television, etc.

7. Recommend that airlines should switch from X-band to C-band radars when purchasing new equipment and when replacing radars in their existing equipment.

8. The workshop needs to have more adequate representation from the general aviation community and the workshop procedure needs to be modified in order that fixed committees can meet with each other.

Conclusion

This report is only a brief summary of the results from the fifth aviation workshop. A full report is given in the proceedings of the workshop (Camp and Frost, 1981) which is presently being published by the FAA and NASA.

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SECTION II
WELCOME
REMARKS

WELCOME REMARKS

Arthur A. Mason

The University of Tennessee Space Institute

Isn't this a beautiful day? I didn't know Walt had such influence. Welcome to the Space Institute and welcome to the Fifth Annual Workshop on Meteorological and Environmental Inputs to Aviation Systems. As you know this workshop is sponsored by the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the Federal Aviation Administration. The people most closely involved in getting it underway and being responsible for making it work are the people in the Atmospheric Science Division of NASA/Marshall Space Flight Center and the Atmospheric Science Division of the University of Tennessee Space Institute.

I'm here to welcome you on behalf of Dean Weaver. Charles H. Weaver is the Dean and Vice President of the Space Institute. For those of you who have been here before, welcome back. I think you'll see that there are some changes that have taken place in the Institute, and that are taking place. Particularaly noticeable is the construction that is going on at the other end of the building. There are some things that have not changed at the Institute; however, and for those of you who have never been here before, I'd like to say just a word about these. The Institute is a part of The University of Tennessee, Knoxville. We are involved in graduate education and research, offering academic programs in many of the engineering areas, in applied mathematics, computer science, and physics, as well as aviation systems. The educational programs that we offer lead to degrees in these fields, both Master of Science Degrees and Doctoral Degrees. We are pleased also to offer continuing educational opportunities for professional people in the way of short courses, conferences, and workshops such as this one that we are hosting this morning.

Because we are a graduate school, the emphasis here is on research as well as on education. We have many people, students, staff, and faculty who are involved in research, and the research is always led by one of our professors, the people who get the ideas, generally get the money, and finally get the work done. We have research going on in several different areas. I'll just mention a few of them to give you an idea of the scope of some of the work we do here at the Institute. We have research divisions in Acoustics, in Atmospheric Science, Gas Dynamics, Gas Diagnostics, Energy Conversion, Material Science, and Remote Sensing. Also several people are involved in various research activities associated with computers, electronics, and optics. All working toward research and being on the frontier of the fields that I've mentioned. What really makes the programs go are the professors. Walter Frost is probably one of the best examples of the kinds of professors that we like to have here at the Institute.

Walt is a professor of Mechanical Engineering; he is the Director of our Atmospheric Science Research Division; he is an entrepreneur par excellence, and incidently, he puts on a pretty good reception for workshop attendees here at the Institute. I think most of all, Walt has the qualities that our productive professors must have. He is very enthusiastic about the work he does. He really gets involved in it. He has a boundless amount of energy, and he is a man who is capable of quality and recognizes it when he sees it. I think that you'll find that is the case with this workshop; at least I hope you will. There will be a lot of activities, a boundless amount of work to be done, and finally, the ability of each of you to recognize quality and to do quality work yourselves.

I think if you leave here with a feeling of enthusiasm and dedication for the things that are being done in this workshop, for helping the aviation community, then the workshop will be a success. I hope that you will find it so. If there is anything that I or my office can do to help you in any way, the door is open. Please call on me or see Dr. Frost, and he, I'm sure will be most willing to help you. Once again, on behalf of Dean Weaver and the entire staff of the Space Institute, welcome to this workshop.

Charles A. Lundquist

NASA/Marshall Space Flight Center

It is my pleasure to welcome you to this meeting on behalf of the Marshall Space Flight Center. I would not only welcome you but want to thank you for coming. We are delighted to see this fine turn out. It hardly seems necessary for me to stress the importance of meteorology to all aspects of aviation. Our center director has a pet phrase for that. He calls it, "preaching to the choir". I'll not try to preach to the choir this morning. On the other hand, every week seems to bring some dramatic event that stresses again the importance of aviation meteorology. Yesterday for example, we had a Vice President flying across the country under very pressing and trying

circumstances. I didn't look at the weather map, but I'm sure that things would have had to have been very bad to have prevented that flight given the urgency of it. So, we had an example there. Next week we have another dramatic event close to the hearts of those of us at the Marshall Center and in NASA; the space shuttle will be launched for the first time. Of course, the shuttle lands as an aircraft on its way in. It is another version of an aircraft. Of course, the meteorology at the landing site is an important factor in that event. We are very aware of the problems that will be, maybe I shouldn't call problems, the situations we'll be facing next week.

Finally, I'd like to extend my thanks to the Space Institute here in Tullahoma. It is a neighbor of which we are very proud. We have very fine working relationships with it, and we are delighted to see it so close to the Marshall Center. We, at NASA, are confident that the meeting will be an outstanding success, and personally, I wish you well in all your deliberations and activities here at the meeting.

A. Richard Tobiason

National Aeronautics and Space Administration Headquarters

Before I tell you about the goals, I think I ought to talk about some of the things that have happened since last year. I think it would help to point out what the challenges are that we face in the next few years. I think the whole era that we're in right now is certainly one of uncertainty. We have a new administration, and we have a new administrator at NASA. We have an '82' budget that is not yet defined. We don't even know what '82' will bring for us. I suspect a lot of the agencies are in the same shape.

The airlines have not done very well in terms of profitability. They're trying to squeeze the most they can out of an airplane for profitability trying to get weight down. The only big variable left in flying now is meteorology. Some of the airlines because of the pressures on economics have reduced the size of their meteorology staffs to a point where they may never get back to having a thorough and competent meteorology staff. Yet, that is what brings us together. How do you get the most out of an airplane in nonhazardous as well as hazardous meteorology. I think that is a real challenge for the industry, and if the industry doesn't have that challenge, I don't know what we have to do for work.

We've got a lot of travel constraints. People you would normally see here from NASA are not here, people like Bruce Gary from JPL. Bruce would normally talk to you about his microwave radiometer, and the tests he's doing in the C-141 this summer. There have been some improvements in clear air turbulence detection over the 1979 tests. Jack Ehernberger couldn't come. If Jack was here he would talk to you about mountain waves, clear air turbulence, and some icing work. From Langley, you'd normally have Norm Crabill and Felix Pitts to talk about lightning. They're out working at Norman, Oklahoma with the F-106 hoping to get more lightning strikes on the airplane. We did have a very successful lightning season last year. A technical memo was published in 1980 on the ten direct strikes that we had in nineteen flying hours. Joe Stickle is here from Langley; however, and Joe can help us a lot with the atmospheric lightning problem.

From Lewis, we normally have Bob Steinberg to talk about commercial aircraft fuel savings, the ASDAR program which is now going into its second phase. The long and short of this program is that it is a way to improve on fuel savings using real-time high resolution winds and temperatures aloft.

There are a lot of things that have happened ~~since last~~ year. I just listed about ten of them not in any particular order of priority. John McCarthy and the National Science Foundation, FAA, and NASA have a proposal on a wind shear program. It has been given the acronym of JAWS. John will give an Impromptu paper on this tomorrow morning. It might be well to reflect on this particular proposal to see how well it matches up a lot of the previous recommendations in wind shear and aircraft performance and characterization of microbursts.

A very significant thing that has happened in the recent year is FAA's move to advance the use and technology of flight training simulators. If you are familiar with that proposal and recommended regulation, you'll remember there are three important phases. One of the requirements for the new advanced simulators is the input of wind shear, icing, and runway performance. Simulations of these are not now available in good form.

There have been a number of meetings between NASA, FAA, and industry on icing research. The Technical Center of the FAA hosted two meetings on icing R&D needs and facility requirements. With this background and that from past workshops as well as conversations with the industry, NASA/Lewis intends to pursue a long term icing research program. This effort will be at a much significantly higher value than we have in the past. Peggy Evanich of NASA/Lewis will be talking about that tomorrow.

There is a new rule out on ozone which became effective last February with a possible one year

delay. The interesting thing about ozone is that airplanes are now getting into the condition where ozone is a consideration in flight planning. How much does it cost to flight plan around ozone? NASA has the Nimbus 7 satellite program directed towards answering this question. We have an ozone sensor on that satellite, and from that we can get real-time integrated values of ozone as well as perhaps the definition of tropopause height. The data from the satellite program is given to Dan Sowa at Northwest Airlines. He is using the data to attempt to predict where airplanes should fly to avoid the ozone hazards. The emphasis on ozone is the reason for a committee on ozone at this year's workshop.

Also, Porter Perkins is here from NASA/Lewis. Porter was heavily involved in the GASP program in the 1977-1978 time frame and can address a lot of the ozone problems.

Jim Luers did some work with Bob Carr at NASA/Wallops on the effect of heavy rainfall on aircraft performance and wind shear. Perhaps, you saw the article on this work in Aviation Week or heard the presentation at the St. Louis AIAA Meeting. There is a lot of work to be done in that area. Bob Carr is here from Wallops and can address this subject. In addition, Jim Luers will speak on it tomorrow.

Last week Jim King of the Safety Board delivered testimony to a house subcommittee on the impact of weather on aviation safety. He makes several points relative to the statistic that 4,000 people have been killed in the last few years in accidents related to hazardous weather. He speaks of the need for real-time weather data observation, very quick dissemination to users, and the need to expedite current programs within the FAA and NWS.

Before getting into the theme, I think I should mention a little bit about some comments that were prompted by Frank Van Demark earlier this year relative to how good of a job are we doing with the recommendations that come out of these workshops. Therefore, tomorrow morning John Blasic representing Ed Gross of NWS, Joe Sowar, FAA, and myself of NASA will attempt to tell you what these agencies have done with past recommendations.

The theme this year, of course, is what the current and future impacts of meteorology will be on aircraft operations and safety. Meteorology is one ingredient that needs a lot of fine-tuning and flight planning relative to operations and hazard avoidance. I think this is a big challenge, and the workshop is a good forum for getting the challenges understood through excellent communication between a lot of concerned people. I would like to thank all of you who will participate in this years workshop.

SECTION III
TOPIC AREA
PRESENTATIONS








METEOROLOGICAL IMPACT ON AVIATION FUEL EFFICIENCY

David E. Winer, Energy Division

and

John E. Wesler, Office of Environment and Energy

Federal Aviation Administration

Changing Priorities

Aviation jet fuel has acquired an entirely new status since 1973: not only is it subject to scarcity, its price has increased by 600 percent in eight years and is still rising! Whereas, the airline industry recently was labor intensive, it is now energy intensive. An important problem in this rapidly changing environment concerns fuel efficient flight creating adequate near-real-time weather information. Specifically, the problem is the lack of highly resolved real-time and near-real-time wind and temperature data at flight altitudes. The existing system, based on twice-a-day balloon observations, supplemented by pilot reports or other occasional data, is simply not adequate for optimum flight planning.

One reason that efforts to solve this problem have not kept pace with the cost of fuel appears to be that the impacts of upper winds and temperatures on fuel efficiency and flight planning are not widely appreciated. Perhaps another reason is the diffuse responsibility for developing new weather products.

The Connection Between Fuel Consumption and Weather Data

Although avoidance of severe weather and resulting reroutings and delays is in itself an important topic, this paper concerns the less recognized impact of wind and temperature on efficient flight planning and flight procedures. Flight in wind has direct effect on fuel efficiency, a qualitative fact that should be intuitively obvious. Quantitative analyses, however, are complex and entail separate study of headwinds and tailwinds for their effects on fuel burn, while an airplane is climbing, cruising, or descending (Gershkoff, 1980). The most important effect is on the ground distance covered by a given amount of fuel, simply based on the forward or backward component of wind velocity as the aircraft is carried by its local airmass. A typical case, shown in Figure 1, was prepared from a computer model, VARYMOD, developed by the Federal Aviation Administration (FAA) for research purposes (Winer and Hoch, 1980). The term on the vertical axis, N(G)MI/KLB, nautical ground miles per thousand pounds of fuel, is a direct measure of fuel efficiency. In this example, a 50 knot headwind decreases the range at the best cruise speed by 3.4 n(g)mi/klb, or 11 percent. The reverse situation, a 50 knot tailwind, increases the range by approximately the same amount. Since winds aloft are frequently well in excess of 50 knots, the resultant fuel savings, or penalties, are truly substantial.

If winds aloft are ascertainable, these relationships between wind and fuel consumption bear upon the pre-flight planning process, particularly on route and altitude selection, and upon in-flight adjustments of altitude. Contrary to the views of some, Figure 1 reveals that speed adjustments to counteract wind have minimal effect, and further, that speed selection is not critically related to pre-knowledge of wind. However, lack of information or incorrect information about the location and altitude of wind fields prevents optimal planning of the flight path and vertical profile and optimum adjustments to these in-flight, resulting in a fuel penalty.

Wind information also affects fuel efficiency via tankering (the use of fuel to carry fuel). An incorrect plan is surprisingly wasteful. When extra fuel must be carried to overcome headwinds, there is a fuel penalty incurred in transporting the added weight, a factor that increases in importance as trip length increases. For example, the excess burn/excess weight ratio on a typical B-747 flight is .2 lb/lb for 3000 nautical miles and .5 lb/lb for 5000 nautical miles. Therefore, large amounts of fuel are burned unnecessarily to carry extra fuel when headwinds are planned but not encountered. When tailwinds are planned but not encountered, the decreased fuel on board reduces safety margins. Two means of overcoming this problem are both wasteful of fuel: either carry extra fuel or refuel enroute.

Knowledge of air temperature aloft is also important in selecting fuel-efficient altitudes. Engines are more fuel efficient in colder air. The optimum fuel efficient altitude is a function of air temperature which affects power and aerodynamic drag. For example, if other factors are constant, a change in air temperature of 10°C affects fuel burn by about 3 percent in widebody airplanes. Accordingly, a fully fuel-optimized plan could require an altitude or track that appears inefficient but takes advantage of best air temperature enroute.

The National Aeronautics and Space Administration (NASA) is currently gathering and analyzing empirical data to define the magnitude of the problem of inadequate data about winds and temperatures aloft. Instead of a purely analytical approach, the NASA study will identify the differences between actual flight plans and path/profiles actually flown, and predicted winds and winds actually encountered. The study will investigate some 20,000 airline transoceanic flights, flown by specially instrumented airliners to acquire wind and temperature automatically (Steinberg, 1981). The FAA Office of Environment and Energy is assisting NASA in this effort. At this stage of the study, preliminary evidence shows that potential savings on the order of two to three percent appear feasible, if flight planning could include more detailed knowledge of prevailing wind and temperature fields.

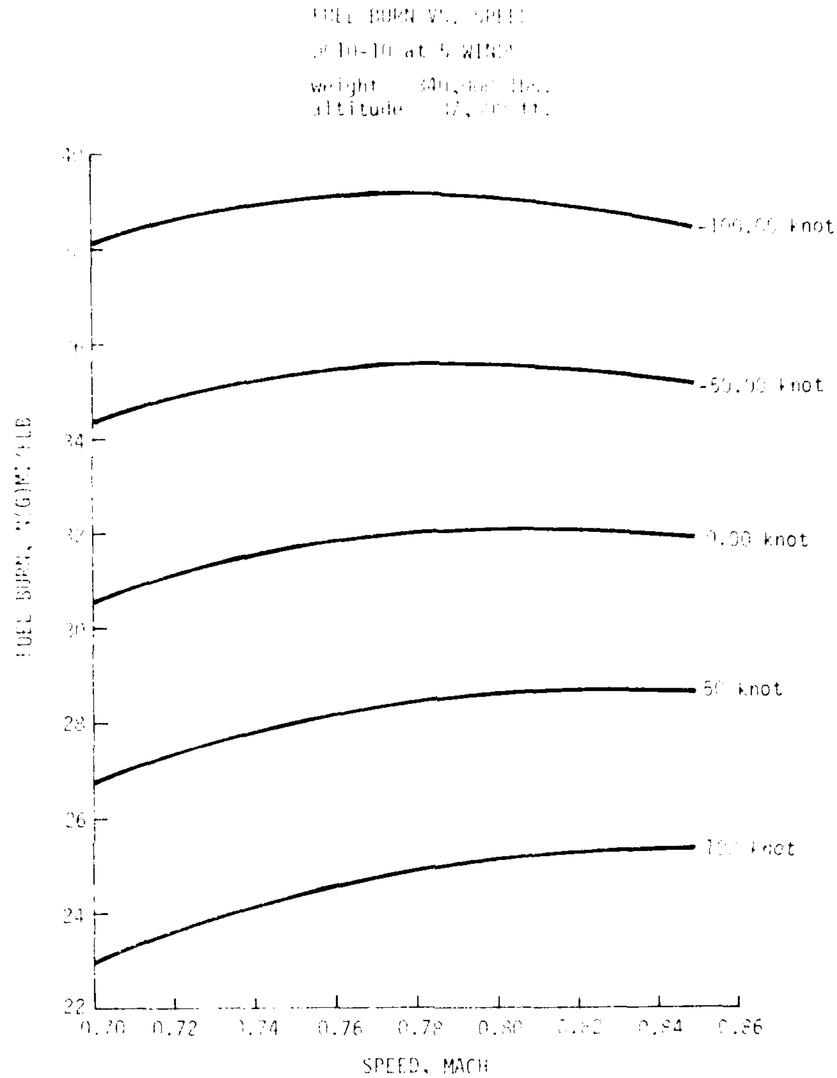

Figure 1. Example of the impact of wind on fuel efficiency in terms of nautical ground miles per kilopound of fuel burned for a DC-10-10 at 37,000 feet. Negative speeds signify tailwinds. Route and altitude selection to achieve the most distance for a given amount of fuel requires wind forecasts for the *projected time of arrival for each segment of a trip.*

The time to recognize the importance of more detailed knowledge of winds and temperatures aloft for flight planning purposes is long overdue. As we shall discuss, technology exists to improve the situation, but no comprehensive, systematic program has been started. The lack of awareness may explain the lack of action.

A 1978 review (Durham and Frost, 1978) of aviation weather research contains 376 references and includes materials on fog, icing, lightning, low level wind shear, storm hazards, and turbulence. Significantly, high resolution data on winds and temperatures aloft are not mentioned. Another comprehensive study from the aviation energy perspective (the other side of the weather/fuel connection) also fails to recognize the importance of wind and temperature data (Covey, et al., 1978). Forty-seven options for conserving fuel in commercial air transportation were identified but improved weather forecasting was eliminated from the recommended list of options for further government sponsorship. Hypothetical fuel saving through improved forecasting, using flight plan optimization, was acknowledged. However, no data were available at the time to quantify the benefit which led to elimination of the option.

During the time of these reviews, the FAA was formulating an aviation energy conservation program through internal studies (FAA Report AVP-78-12, 1978). Here again, the potential of improved meteorology was not recognized. From these three relatively recent investigations, all of which were comprehensive in scope, there were no proposals to bring about large improve-

ments in the quantity and resolution of wind and temperature data.

Using Weather Data: Fuel Models

Even redimentary flight planning uses wind data for computing time and fuel requirements. Before the advent of computers, the process was essentially a manual one, and true optimization was not feasible. The degree of technical sophistication in finding minimum-fuel tracks and profiles was commensurate with the available meteorological data and with the interest in fuel conservation at the time. Almost as a step function, the capabilities for flight-path optimization have appeared. The production of the associated relevant weather products has evolved more slowly.

A host of fuel burn optimization modeling techniques have developed in recent years (Stengel and Marcus, 1976; Erzberger and Lee, 1978; Sorensen, 1979; Collins, 1981). In light of the precision of planning for fuel efficient flight obtainable with these modeling methods, it can be inferred that the practical capabilities of flight planning are limited by meteorological data. The best of these models cannot function properly without near-real-time, high-resolution, enroute wind and temperature data. This is particularly true on long distance routes (Steinberg, 1980).

Bear in mind that full optimization techniques will find the best combination of speed, altitude profile, and ground track covering the entire flight through climb, cruise, and descent. In many cases, adjustments from a precomputed flight plan can be made while airborne, using either on-board or ground-based computers. For such changes, current wind field data are required for the remainder of the flight.

Perhaps the worst case demonstrating the need for timely wind and temperature data is found in transoceanic flight planning. Once tracks and altitudes are assigned on the basis of a plan, there is little change for revision since the separation requirements in open ocean areas are large, and position data for the airplanes are inexact. Accurate and current forecasts along the routes are essential to prevent long flight in adverse fuel burn conditions. The present situation finds us almost totally lacking weather information over trans-Pacific routes.

Technological Capabilities

Fortunately, the technical prospects for achieving the requisite level of wind and temperature data are excellent. In fact, a bewildering array of data acquisition instruments and systems is being developed, from which a superbly detailed flight planning data base could be devised.

The most promising method for the immediate future uses an air-to-satellite-to-ground system known as ASDAR (Aircraft/Satellite Data Relay). In effect, this provides an automatic PIREP (Pilot Report) to a central ground facility, containing airplane position, time, altitude, temperature, wind speed, and wind direction. Experimental use of ASDAR has been quite successful and has led to speculation that the system could be used effectively to improve wind and temperature forecasts for flight planning purposes. Potential savings on the order of $100,000 per year in fuel costs for widebody airplanes have been cited in support of widespread use of ASDAR (DOC/NOAA, 1981). A new variation of ASDAR known as AMDAR (Aircraft Meteorological Data Relay) is designed to work in conjunction with the commercial data communications network known as ACARS (ARINC Communications Addressing and Reporting System).

While ASDAR provides direct wind and temperature data from airplanes equipped with inertial navigation systems, such sophisticated systems are not likely to be adopted for most smaller airplanes. The FAA is investigating an air-to-ground technique that is less costly for the airborne equipment but which can still provide large quantities of data from en route airplanes. Called DABS DL (Discrete Address Beacon System Data Link), it carried out the computations of wind vectors on the ground, using true airspeed and heading transmitted from the airplane while obtaining the complementary ground speed and track data from ground equipment (Wedan, 1980). DABS DL also receives altitude, temperature, and humidity from each DABS-equipped airplane and determine the wind and temperatures aloft for a grid in the ground-based reception area (FAA Report ED-15-1A, 1980).

Both ASDAR (AMDAR) and DABS DL are capable of providing constantly refreshed, high resolution wind and temperature data to a central facility, and it appears that these airborne systems offer the earliest opportunities among all methods for providing the needed data for optimum flight planning. Of these, ASDAR is the more developed and is available for immediate implementation. Satellite-to-ground systems have the potential to supplement or even replace airborne data acquisition systems eventually. These systems, with respect to high resolution determinations of winds aloft, are in the experimental phase and have yet to be demonstrated. Nevertheless, they use demonstrated instrumentation technology and could be highly successful if development continues. Such uses do not appear far-fetched when one considers that operational satellites have been providing half-hourly images of weather patterns to FAA air traffic control centers for several years, and that plans are being made to use satellites in a number of ways beneficial to the aviation weather system (Bristor, 1978).

VAS (VISSR Atmospheric Sounder) is a satellite instrument using visible and infrared radiometry that can detect atmospheric temperatures and winds aloft. It is currently installed in an operating satellite (GOES-4) for determination of its utility in a meteorological system. For temperature measurements, the VAS detects thermal radiation from earth in selected spectral bands which is then used to compute a temperature versus pressure-altitude profile (NASA GOES Data Book, 1980). For detection of wind fields, this

instrument offers three possible capabilities: (1) image sequences from water vapor channels in cloud-free areas, (2) tracking of clouds, and (3) stereo techniques (Schmidt, 1981).

Global wind sensing from satellites using laser radar (lidar) is feasible. The Wave Propagation Laboratory of the National Oceanic and Atmospheric Administration is carrying out the research and development leading to WINDSAT--a satellite specifically designed to detect and report atmospheric winds (Huffaker, et al., 1980). It can be constructed for installation in the space shuttle orbiter. WINDSAT will direct a pulsed CO_2 laser at atmospheric aerosols, and analyze the backscattered radiation along with its own navigation and beam-pointing information to calculate winds in which the aerosols are suspended. Preliminary minimum system requirements call for wind speed accuracy within ±2 knots and directional accuracy within ±10°. Horizontal and vertical resolutions are to be about 150 to 200 nautical miles and 3000 feet respectively. These capabilities nicely match the requirements for optimum flight planning. WINDSAT may also prove useful in wind detection by measuring altitude of clouds in conjunction with cloud motion wind sensing methods.

Although it is not a direct wind detector, the new Total Ozone Mapping Spectrometer (TOMS) installed on the Nimbus-7 satellite measures global daytime ozone fields (Krueger, 1980). Since jet stream boundaries correspond to high gradients of ozone concentration, TOMS is thought to offer an excellent means of confirming and in some cases, delineating the jet stream location (NASA Press Release, 1981). This of course is a crucial determinant in flight planning in order to ride the stream west-to-east and avoid it east-to-west. Such information could be used readily in flight planning computer models. TOMS has another fuel saving potential. Recent FAA regulations require the airlines to control cabin ozone concentrations. TOMS data may be used to avoid routes that carry an aircraft into known high-ozone concentrations in the atmosphere. This in turn alleviates the need to fly statistically satisfactory routes (from an ozone-concentration standpoint) that are not fuel efficient, or to carry ozone detection instruments that add fuel-consuming weight to the airplanes. Navigation around or under high ozone regions identified by TOMS is under actual evaluation by NASA and FAA in cooperation with an airline at this time.

Ground based wind and temperature detection may also be expected to provide flight planning data. Supplementing the traditional balloon systems are possibilities such as the FAA AWOS (Automated Weather Observation System). There may be as many as 1000 of these eventually installed and transmitting surface observations.

A Proposed Approach

We have described the need for improved wind and temperature data to complement the developing fuel optimizing flight planning models. What can be done? Given enough time, the problem might be solved piecemeal by evolving research and development, but as noted previously, the rate of development is already at an imbalance with rising fuel costs. The problem can be attacked head-on and should be by an interagency effort in cooperation with industry to develop a weather data system specifically designed for fuel-efficient flight planning.

This task is not as formidable as it might appear because the agencies and technical means already exist. An outline, of the proposed system is shown in Figure 2. Data should be gathered from any sources that can provide information with the required precision and accuracy. Considering the enormous quantities of incoming real-time or near-real-time data, it is mandatory that automatic preprocessing and quality control be carried out before loading the current wind/temperature data in the flight planning data base. As for forecasting to the time requirements of immediate flight planning, it appears that human intervention will be required, but the burden must be carried mostly by computer programs.

At present time, it is impossible to quantify the fuel-saving potential of such a system. First, the precise requirements of the best optimal flight palnning models are not defined. Second, the precise capabilities and distribution of the various data acquisition systems, near term and longer, are not well known. (We assume that no technical limitation exist with respect to telecommunications and computers.) Nevertheless, the fuel and cost savings that would accrue from this system are undoubtedly very large and probably far exceed the cost of implementation and operation. Each one percent of jet fuel saved amounts to 120 million gallons or dollars not wasted per year by U. S. air carriers and general aviation.

The FAA is responsible for promoting and encouraging fuel conservation by aviation system users (DOT/FAA, 1981). Participation in the formation of an effective flight planning data base offers an excellent opportunity to carry out this responsibility. Our Office of Environment and Energy intends to investigate further the feasibility of the proposed flight planning system, including detailed projections of the costs and benefits. Presuming a favorable result, interagency cooperation and approval will be sought.

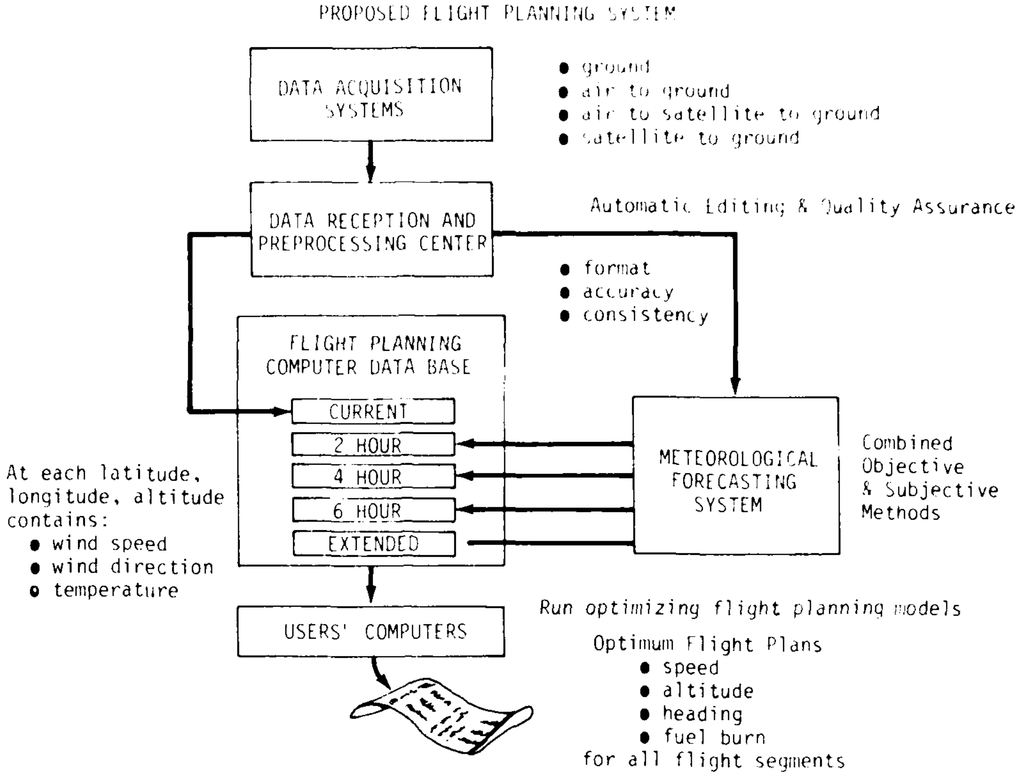

Figure 2. A conceptual plan for development of a wind and temperature data system that is specifically tailored to the needs of flight planning. Such data are essential for maximum fuel savings that can be determined with new fuel-burn optimizing models.

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METEOROLOGICAL INPUTS TO ADVANCED SIMULATORS

Gordon O. Handberg

McDonnell Douglas Electronic Company

Introduction

The earliest instrument flight trainers incorporated representations of weather conditions. These conditions were selectable in the sense that training could be conducted in different climactic conditions at the will of the flight instructor. Today's flight simulators, most of which are still employed for pilot training, represent weather in a considerably broader sense and with an almost limitless capability for future expansion.

"Realism" is a word commonly used in describing flight simulators. This word brings satisfaction to the simulator designers and reassurance to the people who have invested so heavily in such equipment. Realism refers to many aspects of these machines, not the least of which is weather, and helps greatly to promote simulator acceptance by the pilot community.

Realism in simulators is, thus, vigorously pursued and greatly appreciated. It has long been a measure of simulator adequacy as a training device mainly because the psychology of the learning process is insufficiently understood to confidently substitute anything else. Realism is manifested in many forms: the "feel" of the control column during maneuvers, the sound of the main gear thumping on the runway at touchdown, the visual sensation of the runway edge lights flashing by outside the windscreen. All of these and more combine to make a simulator a satisfying substitute for the actual aircraft. To that extent along, it is a valuable training goal. Contemporary simulators go beyond this point, of course, by providing a more controlled training environment than that attainable during real world operation of an aircraft.

Realistic weather is important in pilot training simulators. It offers an uncommonly promising opportunity to provide training because it permits an element of environmental control not available in the real world.

This paper describes weather simulation as it is currently implemented and offers some suggestions and questions to be considered in future simulator developments.

Weather in Current Simulators

Simulator technology already provides an impressive array of weather representations. Some of these representations are more realistic than others; some are more useful than others. In total, weather effects and combinations of weather effects available to the simulator instructor (literally at the touch of a button), far exceed the time available to use them during a training program. Here is one way of describing the meteorological conditions normally simulated in a contemporary simulator:

(a) Standard atmospheric profiles of pressure and temperature with altitude, plus selectable variations for non-standard conditions

(b) Winds, wind shear profiles, and turbulence independently selectable in magnitude and directions

(c) Cloud, fog, and haze effects, with selectable heights and densities, and also with patch occurrences such as scud clouds

(d) Thunderstorm effects, with lightning flashes

(e) Some residual precipitation effects such as braking effects of scattered ice on the runway

(f) Specialized icing effects

Some of these effects are more useful in any particular training syllabus than others.

Perhaps the most technically challenging area for future additions and improvements resides in the out-the-window visual imagery. Most simulators now employ CGI (computer generated imagery) visuals. The ability of current CGI visuals to simulate weather is listed in Table 1. This example

TABLE 1

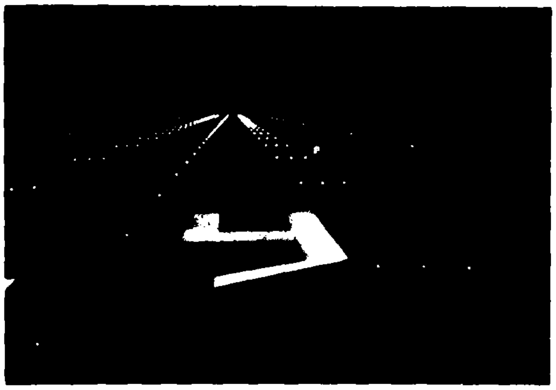
[illegible]

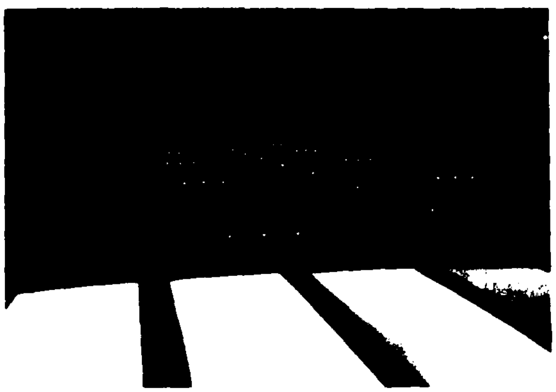
Fog (homogeneous)-with selectable intensity
Ground Fog
Cloud Layer-with selectable top & base heights
Scud Clouds-Random Occurrence
Directional Horizon Glow
Cloud/Fog Reflection of Aircraft Lights
Lightning Flashes and Lightning Bolts
Rain on Windshield
Night, Twilight, and Low Light Level Day
Moon and Stars

applies to the VITAL IV equipment as presently being installed by McDonnell Douglas Electronics Company on new and old simulators (both airplanes and military [illegible]. Figure 1 is a photo of a VITAL IV scene [illegible] visibility situation of

3,000 feet RVR (runway visual range). Figure 2 shows an RVR of 800 feet selected by the flight instructor. The visual effect of a lightning bolt is captured in Figure 3; the flashing sky brightness effect that accompanies the lightning is present but not apparent from the photo. Figure 4 depicts a clear night with stars and moon.

One acclaimed quality of CGI visual equipment is the consistent and calibrated accuracy of an RVR value as illustrated here. For a structured training syllabus, this kind of repeatability is an important asset. It is also, regretably, a departure from realism in that the capriciousness of actual weather is missing.





Changeability

When the instructor in a flight simulator selects a wind from the east at 15 knots, what he gets is a wind velocity of 15.0 ± 0.0001 knots from 90.0 ± [illegible] degrees. Such accuracy, precision, and constancy is a virtue in many instances. But is it desirable for weather simulation? In actual flight operations, a pilot receives information about the weather from pilot reports or from ground station observations. He knows that the information given to him may be approximate, that it is predicted, that it may contain human errors, and that current reports may reflect actual conditions existing one or more hours earlier. So when he embarks, he carries with him a set of apprehensions that contributes to his decision-making and affects his flying behavior. That same pilot, in his annual simulator check ride, divests himself of those apprehensions (although the instructor will give him a few other reasons to be concerned) and thus, conducts himself differently than he would in the real world.

The effect of this lack of weather capriciousness on the training and checking process is not known. It could include the emotional (in which case it will probably never be understood) and the equitable. This latter effect alludes to the principal use of some training simulators as a proficiency check or testing tool. If testing or checking of skills is not done in a uniform and equitable environment, the results may not be acceptable to the participants.

It is certainly possible to simulate weather with a degree of erratic behavior built in. The 15 knot crosswind selection, as an example, could be simulated so that the result is a mean speed of 15 knots with variations up to ± 5 knots and a direction of 90 degrees with variations up to ± 20 degrees. If two pilots undertake an approach as a test of proficiency, and one of them encounters a reduction of 5 knots just before touchdown, and the other encounters an increase of the same amount, their landing abilities will not have been tested uniformly. When license renewals are at stake, the uniformity of testing cannot be treated academically. Similarly, when an actual approach is begun with a reported Category II situation on the ground, the pilot can expect to experience some reasonable variation from 1,200 feet RVR when he passes his MDA (minimum decision altitude). In a simulator approach, on the other hand, he knows that the view of the runway awaiting him will contain no surprises. Deliberate variability can result from algorithms originated from known statistically derived patterns. Such variation patterns can be modeled into RVR and wind shear profiles and other effects. The question that needs to be addressed is: to what extent is such changeability helpful to the training and checking process for which increased realism is a known advantage?

Future Improvements

Some improvements to present simulator practices can be made without waiting for technological change to occur. The tools are here now and waiting to be used more productively. Other improvements will be paced by advances in the capability of simulator equipment. All improvements, however, should be incorporated only as (a) required by the pilot training expected and (b) justified by authentic meteorological occurrences. Thus, simulator developers need inputs from both the training community and the meteorology community in order to make useful improvements.

One tangible example of an existing statement of future training requirements is shown in Table 2. This is a summary of simulated weather requirements stipulated by the FAA for U.S. Air Carrier training. These weather requirements are extracted from the Advanced Simulation Plan (FAA, Federal Register, 1980) under which airlines may perform a larger percentage of pilot training in simulators of greater capacity. The ultimate plateau, called Phase III, implies complete simulator training, and thus, dictates the most complete representation of the aircraft and of the weather environment.

This and requirements statements from other sources give some direction to simulator designers, but presently only from the broadest sense. Note, as an example, the Phase III requirement for supplying the visual effect of "entering precipitation near the thunderstorm." What one immediately envisions is an expansive three-dimensional panorama in which a distant but easily recognizable complement of rolling thunder-clouds is partially hidden behind a wave of precipitation. Current visual simulation equipment, however, computes imagery that

TABLE 2

SIMULATED WEATHER REQUIREMENTS OF FAA

(AC 121-14B)	(AC-121-14C)		
VISUAL SIMULATORS	PHASE I SIMULATORS	PHASE II SIMULATORS	PHASE III SIMULATORS
Cross wind	Crosswinds on Ground	3-Dimensional Wind Shear	Rough Air
Instrument Conditions		Runway Conditions: Dry, Wet, Icy, Patchy Wet, Patchy Ice, Wet on Rubber Residue	Cobblestone Turbulence
Cat. I, Cat. II, Cat. III			Airframe Icing
Varying Wind			Daylight, Dusk and Night
Reduced Visibility		Precipitation Sound	Daylight Cockpit Environment
Cloud Base Selectable		Dusk and Night	Full Color Visual
		Variable Cloud Density	Sound, visual and motion of entering precipitation near a thunderstorm
		Partial Obscuration, or Broken Cloud Deck	
		Gradual Breakout	Wet and snow-covered runways in visual scene
		Patchy Fog	Weather Radar
		Fog	
		Cat. II and Cat. III	

looks disturbingly polygonal. Newer techniques such as texturing and circular surface algorithms will take us a step closer to the preconceived image, but the technology may not get us fully there for ten or twenty years at an affordable price. In the meantime, some achievable compromise needs to be identified so that development work may be directed towards something that promises useful results.

Visual simulation is without a question the area in which future improvements to present capabilities are paced by technology advances. So far the visual developers have sought (and achieved, to an impressive extent) a close approximation to the real world as observed through a cockpit window. Much of the realism derives from the absence of visual objects rather than from their faithful representation. Nighttime operations and low-visibility conditions are used very successfully simply because the trees, cars, cows, and fences that cannot be computed and displayed anyway are understandably missing. The result is a believable view out the windshield and a useful training tool.

More advanced simulator applications call for specific meteorological effects geared to specific training requirements.

Meteorological Inputs Needed for These Improvements

By seriously addressing each of the following generalized questions, the specialists in meteorology and the specialists in pilot training can bring together some useful inputs to the specialists who will provide the future simulator equipment.

1. Select the conditions. For all meteorological conditions known to affect flying which should and which should not be made part of a simulator training exercise? A four-hour simulator check is already filled to capacity with activity; our zeal to add more weather effects must be directed towards results that will be used.

2. Reason for simulating a condition. What is the purpose of incorporating each condition selected? For example, is a thunderstorm to be simulated to teach recognition and avoidance, to teach penetration technique, or merely for a more realistic setting?

3. Combined conditions. Which combination of conditions occur often enough to justify incorporation as special combinations? An example might be a frontal conditions that produces both wind shear and icing on approach.

4. Required effect on the pilot. By what means (i.e., visual, sound, feel, or motion cues) are the effects of the simulated condition to be provided to the pilot? For example, a wind must manifest itself in relative heading and ground speed/airspeed relationships, but is it also necessary to reveal itself in smoke direction on the ground?

5. Fixed or caprice. For one given type of condition, should variations of intensity be incorporated on a programmed basis or on a randomly changing basis? Wind shear, for example, could be imposed upon each pilot in three specific profiles to assure equal exposure to a known range of conditions. Conversely, it could be imposed in some unpredictable manner.

6. Room for growth. To what extent should provisions for "new" conditions be allotted? Recently, (Aviation Week & Space Technology, 1981) it has been suggested that prevailing opinion on one cause of landing incidents has been misdirected towards wind shear, when the real culprit may be massive rainfall effects. A simulator built now to continue in operation for fifteen years must be able to accomodate such changes.

A challenge is presented by these questions. Answering them deliberately with sound meteorological inputs will result in better and less costly pilot training in future simulators.

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Question and Answer Discussion

(Unidentified): What is the typical cost in capital outlay in maintenance on these simulators that you were talking about in the next couple of decades of having to nuture and keep going?

Gordon Handberg: That's a good question. They're very expensive. The airlines are paying, correct me if I'm wrong Carl (Terry), but it's about six to seven million dollars each.

Carl Terry, United Airlines: Five to seven million, last year, exclusive of visual systems and you can answer the question on what they cost.

Gordon Handberg: Oh, they are dirt cheap. Visuals are about a million dollar package, and the simulators themselves are as Carl (Terry) says about five to seven for the airlines now. Keep in mind that the government buys things differently, and the government has different needs. They do buy a different type of simulator equipment and because of that the military simulators tend to come out quite a bit higher.

They're up in the ten to twenty million dollar a copy cagetory.

Carl Terry, United Airlines: I was going to say that I believe that price is for an existing technology machine airplane. The 767 and 757 simulators run 30 to 40 percent more at least because the simulation of or the job of simulating the airplane itself is so much greater.

Warren Campbell, NASA/MSFC: What size or type of computer do you use with these simulators?

Gordon Handberg: In the simulator itself?

Warren Campbell: Yes.

Gordon Handberg: Different manufacturers use different types. I guess Radifon is using the SEL-32 series. CAE is using the Deck vax 11780. I don't know what Link is using now. What size? They are normally a 32 bit machine now -- the newer ones.

Warren Campbell: How many words can it store?

Gordon Handberg: Carl (Terry), why don't you answer that.

Carl Terry: The load is not so much the size. I think we're probably looking in the existing areas on the order of probably about 150,000 words tops, and probably double that for some of the later airplanes because the high technology systems have to be simulated. The real load is in instructions per second. At present, we're probably looking at in excess of one and a quarter million instructions per second requirement, close to one and a half million per second. The 767 series airplanes - I think Link is planning to use two cell 3285's. Radifon is using two on the 747 now. CAE will try to use two vax 11780's if Deck can get their shared memory working.

Robbie Robertson, ALPA: I guess thinking of the cost that you're discussing and realizing having spent many hours in your simulators under proficiency checks, the testing procedure is very structured now, and most of the testing that occurs is regarding low weather approaches. That is really the critical thing, and that tends to be stable weather. The very low RVR's that we use break out tends to be stable weather. I was just wondering in reviewing the cost and realizing the people you're testing are mostly experienced airmen whether the cost is justified, or the need justifies the cost to subject the experienced airmen. You're not teaching people to fly but basically with the exception of possibly wind shear, teaching them weather phenomena that they experience in everyday operation when the reality of the testing is how they handle the airplane under the worst conditions of getting it on the ground. Ice and the more stable conditions appear to me to be adequately covered in today's simulators, in today's simulators without the addition. I'm just talking about when you referred to the cost of putting in the sound of thunder, lightning, and various other effects. Is that really necessary in the environment that I'm talking about now when only the airline pilot and his evaluation in the four hour simulator ship is once a year?

Gordon Handberg: You have a good point there. There is a cost effectiveness question that should be addressed more strongly than it is. I think very often it is not addressed sufficiently. I know one simulator that has programmed into it ten thousand radio stations. That operator has probably never flown over five hundred of them in their training program, but they're all there. Somebody paid for it.

OPERATIONAL PROCEDURES RELATIVE TO SEVERE WEATHER

James F. Sullivan

USAir, Greater Pittsburgh International Airport

Severe weather can have a tremendous impact on both safety and the economics of all types of aviation.

It is through the cooperative efforts of many government agencies and aviation professionals that this impact can be reduced or eliminated.

Being airline oriented, I can only cover with accuracy, the operational procedures which exist and penalties that must be paid when severe weather occurs and touch on the cooperation received from the National Weather Service and the Federal Aviation Agency.

The job of determining what procedures are to be used relative to a particular instance of severe weather falls mainly on the dispatcher's shoulders. He must make decisions and plan the flight at least two hours before the scheduled departure time, usually well before the flight crew reports to the airport for their flight.

Airline dispatchers are highly trained individuals, licensed by the FAA at the same knowledge level as a Command Pilot. They have an average of 22 years experience. To meet the license reqirements, dispatchers must be good practical "weather men". They must have the ability to read and interpret surface and upper air weather maps, understand principals of forecasting, the dynamics of air masses and frontal systems, and most importantly, understand the effect of all these factors in each individual airport which is served. They must also be knowledgeable in the principals of navigation, communication systems, air traffic control procedures, Federal Air Regulations, and must understand aircraft systems and their operation on not one, but all the aircraft in the air carrier's fleet. They must be able to speak the language of the operating crews as well as that of management.

Well before a flight is scheduled to originate, the dispatcher collects information from many sources. From company stations, he receives field condition reports; from the maintenance department, aircraft availability and minimum equipment list items that are inoperative; is the radar working? From reservations, he receives passenger counts; from crew scheduling, crew availability; from the National Weather Service and FAA, weather forecasts, winds aloft, NOTAMS, and pilot reports.

Using this information, a plan of operation is developed for each flight. When the crew arrives at the airport, this plan is presented to the captain for his approval. An agreement is reached between the captain and dispatcher, and they each sign a release stating how the flight is to operate. After the flight departs, important coordinating functions must be performed by the dispatcher between the flight and other departments of the airline. The dispatcher also provides advisory information affecting the safe progress of the flight.

During periods of severe weather, an alternate plan of operation is agreed upon in case the flight cannot be completed as planned. Additional fuel is boarded for holding or deviations around areas of weather. Information is received by the airline from many sources during the period of anticipated or actual severe weather. A few airlines still use low speed 100 word per minute printers in the station operations offices, but the dispatch offices have medium speed 1,200 BAUD or high speed 2,400 BAUD circuits direct from the National Weather Service Circuit Center in Kansas City, Missouri.

Surface weather observations received over these circuits include SIGMETS, CONVECTIVE SIGMETS, storm warnings, PIREPs, radar reports and forecasts. In addition to these items, other information is received from FACSIMILE circuites such as MAFAX or DIFAX. Facsimile grey scale radar print-outs are obtained from Alden or Scanatron machines. Satellite pictures and the most important tool to arrive on the scene in recent years, the digitalized video color radar produce additional important data on severe weather location and intensity.

Let's look at how this information is acted on and disseminated. All surface weather reports showing inclement weather, SIGMET REPORTS, forecasting turbulence or icing, convective SIGMETS (which are published for the following five reasons: (1) tornadoes, (2) hail 3/4 of an inch or greater, (3) imbedded thunderstorms, (4) squall lines or (5) an area of level four or greater thunderstorms). This information along with PIREPs of severe weather are all relayed to affected flights. Several methods are used to communicate to the cockpit. The principal ones are teletype circuits or phone to the nearest company station for relay to the flight, or in most cases, use of company radios (enabling direct dispatcher-pilot discussion). Soon a digitalized system (ACARS) will allow excellent voice or digital print-out capability in the cockpit virtually anywhere. When a radar report is received over the NWS circuits showing a level four or greater report, or when a convective SIGMET is received or if a weather report shows thunderstorm activity, the dispatcher is required to call up a color radar picture of the area.

Because of the limited range and resolution of aircraft X-band radars, pilots at USAir have come to rely on the S-band color weather radar in the dispatch office to give them more accurate information on what's ahead. This forewarning allows better use of the on-board X-band equipment.

After the radar picture is received by the dispatcher, a radio contact is made with the flight, and the captain is advised where severe weather areas are, the intensity and suggested routings to avoid these areas. Encounters with severe weather can impose a tremendous economic burden, to say nothing of the safety impact on any airline. The additional fuel that must be carried

for holding or rerouting creates a double burden-increased fuel burn because of the increased weight of the fuel! It is estimated that for each pound of excess fuel carried, the burn will increase by one percent per hundred miles flown. For example, a flight that must carry an additional 5,000 pounds of fuel on a 500 mile flight because of weather, will burn 250 pounds of extra fuel.

Flights that have to be rerouted, or held due to adverse weather, affect other flights from two aspects: other flights in the same general area are often held or rerouted in turn, and aircraft absorbing delays are usually scheduled to fly subsequent flights. Once a flight is delayed enroute, it often delays other flights. The result varies from broken passenger connections to disrupted gate usage plans, to blown aircraft maintenance schedules. This can even translate into a delay or cancellation the next morning. Should the flight have to divert to an unscheduled airport not served by the carrier, ground personnel at that airport must be paid to handle the flight. Fuel costs at these airports are usually far more than at the one the carrier serves, and abnormal communications double and triple the time required to get back underway. Should a diversion occur during meal time, the passengers must be offered food service. Crew time becomes critical. Most flight crews are scheduled close to their eight hour daily limit, and any additional flying could result in a legality problem where a crew must be given additional rest. This could also delay a flight or necessitate deadheading an additional crew to the aircraft to be able to meet the schedule requirements.

When a discussion of severe weather takes place, it is usually about thunderstorms, but equally important to airline operational procedures are clear air turbulence, icing in clouds, freezing rain or drizzle, snow, and wind shear. Each of these situations could and do bring additional operational procedures.

Clear air turbulence is difficult to forecast, and usually the first knowledge of its existance is from a flight encountering moderate to severe conditions. This requires immediate assistance of air traffic controllers for alternate altitudes and for dispatch offices to start refiling alternate routings to avoid these areas. Icing in clouds require basically the same procedures but bring into play a different set of landing and takeoff minimums. Operating in known moderate or severe icing conditions is not allowed. However, a descent or climb through known moderate may be made provided the departure airport has ceiling and visibility minimums of 800-2, 900-1 1/2, or 1000-1 and conditions are suitable for the aircraft to return and land should severe icing be encountered. The arrival airport must have the same minimums, and the moderate icing conditions must terminate at or above the final approach altitude.

Freezing rain or drizzle present different problems. Aircraft parked at terminal gates become coated with a layer of ice that must be removed prior to departure. Deicing fluid now costs between $3.80 to $4.60 a gallon, and it is not unusual to use 200 to 300 gallons for a single airplane. Additional time is lost in deicing that cannot be made up. Runways become hazardous, and the dispatcher must make the decision in advance of origination if this flight can operate safely with these conditions. If he decides it cannot, and the flight is cancelled, passengers must be notified before they leave their home or office, if possible. Subsequent flights must also be cancelled or the aircraft must be ferried to another city for the origination. It is useless to attempt to serve a city having freezing precipitation by providing surface transportation from another city. For example, should Louisville, Kentucky be cancelled due to freezing rain, we would not use Cincinnati, Ohio as a provisional airport. If it is too slippery to land a flight, it's equally as hazardous to try and bus passengers between the two cities. It's far better for all concerned to not operate at all.

Snow offers all the problems that freezing rain or drizzle do plus the problem of slush and snow depth. Operators of aircraft with aft mounted engines must take special precautions to avoid ingestion of large amounts of water or ice and causing flame outs. Additional procedures are enacted by the dispatcher to obtain depths of snow or slush to determine if the snow is wet or dry and what is going to be done about it.

Phone calls are placed to local company station managers, snow committees, FAA towers, and airport managers to find out this information. Flights are delayed, rerouted, or cancelled depending on the severity of the conditions and the ability of the airport personnel to cope with these conditions. During the fabulous winter of 77-78, Buffalo, New York Airport was never closed, but the city was. With over 53 inches of snow in both December and January and temperatures well below freezing, there were times nothing moved within the city for days, but yet the airport was able to keep their runways and ramps open even though no one operated in or out. The point is decisions and procedures must also be based on the ability of local personnel to be able to cope with severe weather conditions. With four inches of wet snow on the runway, it's improbable some aircraft could ever attain enough forward speed to lift off irregardless of the runway length.

Wind shear is a hazard the pilot must be aware of well in advance. Any reported wind shear received in a dispatch office is immediately relayed to affected flights. Again, we have a condition difficult to predict, but the dispatcher and pilot must assume it will exist under certain conditions. Again, plans must be made for holding or diversions when wind shear is suspected to occur.

Operational procedures must be timely and well conceived to assure the least amount of impact on airline operations. In this competitive age of survival of the strongest, sound operational management, especially in handling the impact of

weather, plays a sizable role in the ability to compete.

Question and Answer Discussion

John McCarthy, NCAR: You said that USAir will have NWS radar uplinked to the cockpit. When?

James Sullivan: We don't have a date when. Republic has successfully done it. They have projected Miami radar pictures into the cockpits in Minneapolis. It is still in the experimental stage through Kavouras systems which is based in Minneapolis.

John Hinkelman, FAA: How do you feel about the FAD program at the FAA? You know the Fuel Advisory Program where you stay on the ground until you can get a slot.

James Sullivan: We're all for it. We feel that any way that we can save fuel; we'll cooperate 100 percent. We like it very much.

Rob Robertson, ALPA: In fifteen years of flying for a major airline, I must say that the dispatch in the weather departments of the airlines and the FAA do an exceptionally good job. I don't think, with the exception of Denver and a lot of funny things happen at Denver, was I ever surprised by severe weather, but I wonder in the present day fuel conscience area if we're not developing another problem area, and that is reporting even light turbulence, various factors that will affect a flight plan. We're no longer in the business of carrying fuel, and if we have to drop to a lower altitude, it becomes a problem. I don't guess it is really safety related, but it is certainly passenger related. I see a severe lack in the ability of the FAA, and even the various airline weather departments to get real-time updates to the flight crews about chop or moderate turbulence at particular altitudes so that when you look at a flight plan, you can say it is planned for 35,000, but I'm going to put on another 1,500 or 2,000 pounds because it looks like even though it is flight planned at 35,000 to get the kind of ride that I'd like to have for the people that want to go at 31,000. That's an area to me as a safety representative for the pilot's union, I hear a lot of complaints about. I don't guess it is safety related, but it is certainly an area that needs to be looked at.

James Sullivan: It's comfort related, and I agree with you. We're looking at a system called MCIDAS. I don't know if too many of you people are familiar with it. It's a relatively new system developed by the University of Wisconsin that takes the input of the color radar, circuit 604, facsimilie circuits, and satellite pictures, and puts it into a computer. What we have seen from this system is absolutely fabulous. They're not selling weather packages in any way. They're just selling a computerized system, and the National Storm Center, I understand, out in Kansas City has installed this system. It's something for the future.

Andy Yates, ALPA: Getting back to what Capt. Robertson was talking about, real-time update primarily with regards to winds has been one of the problems that I've noticed. We have; for example, going between San Franscisco and Honolulu, literally hundreds of airplanes reporting the INS winds, but unfortunately, they only go to their own airplanes. There are very few times that the airlines will talk with each other or pass the information on to ATC or to the FAA so that everybody can take advantage of this. I would suggest that somehow or another the airlines start talking to each other about this because this is really where a lot of the fuel savings can occur.

James Sullivan: Andy, that is a good point. I'm on the Airline Meteorological Committee, and that point has been brought up in the past. American Airlines is inputting this information directly into NWS computers. It's still, I understand, in experimental stages of what they're going to do with it as far as updating a real-time on their winds. This MCIDAS system is another we've found that is accurate within 20 knots which doesn't sound like too much, but it's a tremendous improvement over what is available right now.

Jim Luers, University of Dayton: Do you issue any frost forecasts or do you people deice your aircraft when they have frost on in the morning or do you take off with frost?

Jim Sullivan: We do not take off with frost. We get laughed at in Memphis all the time, but we will not take off with frost on the airplane. It must be deiced.

Jim Luers: You don't try and forecast it the evening before or anything like that do you?

Jim Sullivan: Yes, we do. We try to tell the areas that are going to have frost to anticipate it. This prevents icing delays, and their equipment is ready for the morning.

METEOROLOGY IMPACT ON FUTURE AIRCRAFT DESIGN

Joseph W. Stickle

NASA/Langley Research Center

Introduction

When Dr. Frost called to request a presentation from NASA/Langley on meteorology impact on future aircraft design, Dr. Houbolt and I agreed that there are upcoming changes in both design and operations that will be heavily influenced by the meteorological environment. Since both of us would be in attendance at the meeting, we decided to share the podium, with John discussing future and more nonconventional designs while I project meteorological impact brought about by operational changes over the next few years.

Discussion

Figure 1 illustrates the spectrum of airplane designs comprising the general aviation fleet today. Aircraft in sizes ranging from one place to twenty passengers, and having cruise speeds from 30 to 500 miles per hour perform a multitude of functions including personal travel, business activities, and flight training.

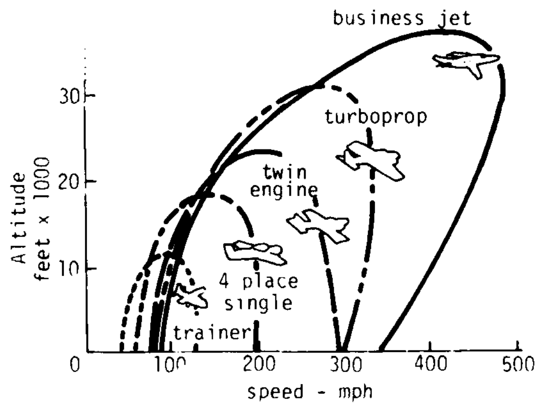


Figure 1. Range of types and performance of general aviation aircraft.

There are two changes within this fleet that I foresee in new designs being impacted by meteorological factors. The first is in the areas of primary training and sport flying. The cost of flying has risen to a level that is beyond the reach of the average American wage earner to participate for the sole purpose of pleasure or to maintain more than a minimum of proficiency flying hours. As an example, five years ago the rental cost of a 2-place trainer in my local area was between $11 and $14 per hour. Today, that same airplane rents for between $20 and $28 per hour. The result is that the flying hours in the Aero Club to which I belong has dropped almost 25 percent during the past year. You might ask, "am I projecting the demise of sport and proficiency flying?" The answer is "absolutely not!" I am suggesting, however, that low cost alternatives are becoming available that will impact that class of airplane. A recent article I read in the AOPA magazine attributed a major factor in the survival of personal flying during the depression years to the Aeronca C-3. This airplane and its success reduced the cost of flying from about $11 per hour which was common in military surplus aircraft to less than $3 per hour. Human ingenuity appears ready to revisit the low operating cost arena with designs such as those illustrated in Figure 2. Powered Ultralight aircraft, powered sailplanes, and efficient homebuilt airplanes are each experiencing rapid growth in the market place. All of these operate on less than 3.5 gallons per hour and the "Polywagen" is advertised to cruise at 200 miles per hour carrying two people plus baggage. My projection is that a large part of sport and pleasure flying will be accomplished in this performance class of aircraft in the future. Whether these airplanes will be built by the major manufacturers and certificated under existing rules is questionable. Traditionally the profit margin on conventional two-place training aircraft is so low that it precludes major year-to-year changes in design. However, if the competition develops either through the homebuilt route or a new manufacturer entering the market, the major manufacturers will respond and the aviation community as a whole will benefit.

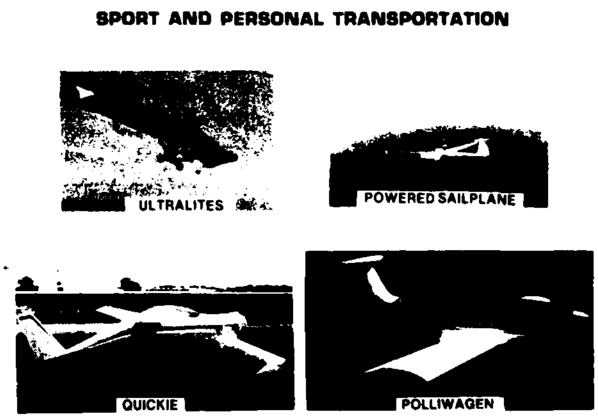


Figure 2. Photographs of existing low operating cost airplanes.

What does all of this have to do with meteorology? The fact that many of the configurations coming out of the homebuilt area are nonconventional and most are capable of very slow flight raises the age-old concern of flight in turbulence. I don't see a particular need for a better definition of the turbulence environment but rather a challenge for the designer to cope with the handling quality problems and safe operation of his airplane. In many localities, gusty conditions of 15 to 20 knots are not uncommon. For an airplane with a stall speed of 20 to 25 knots and a cruise speed of 50 knots, operating in turbulence will be a

major safety concern.

There is another class of airplane that I feel will be emerging in the near future. It is the high performance single-engine airplane that should find its way into the business aircraft fleet. Figure 3 illustrates the trend in general aviation airplane lift-to-drag ratio since the 1920's. You will note a gradual increase in lift-to-drag ratio which is a measure of efficiency of airplanes over the years, but there is nothing dramatic or outstanding in the way of improvement shown. For comparison, a modern jet transport can achieve a maximum value of about 17 to 18. Several years ago, NASA identified a goal to build the technology base to allow general aviation designs to operate in the range of 18 to 20. As a matter of interest, the LearFan which is now in flight testing, should be capable of operating in the range of maximum L/D from 17 to 20. Cruise speeds of this class of business aircraft will be in the 300 mph plus category, and they will operate at altitudes up to 35,000 ft. Because they are business vehicles, schedule reliability will be of prime importance meaning that all-weather operation will be a design feature. There is a need for improvements in weather detection, prediction and avoidance, especially in areas of thunderstorm hazards such as lightning, hail, wind shear, and turbulence, and in icing.

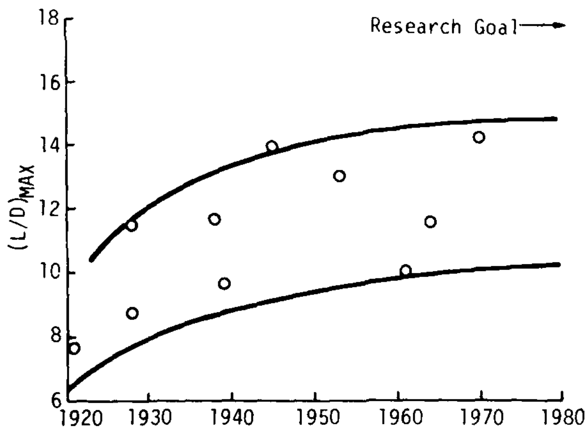


Figure 3. Trends in maximum lift-to-drag ratio of propeller-driven aircraft.

Another feature of the high performance business aircraft is that it will likely take advantage of natural laminar flow at least over the wing surfaces. Laminar flow was a hot issue in the early 1940's when NACA developed its six series of airfoils. Unfortunately, manufacturing of production wings using aluminum skin and riveted construction did not have the smoothness and waviness required to achieve laminar flow. In addition, the airfoil series developed by NACA had a significant loss in maximum lift when laminar flow was not present. This change in maximum lift could have been a safety concern when operating in rain which would cause transition from laminar-to-turbulent flow, or with bug-laden wings where the expected maximum lift would not be available. The use of composite construction has now circumvented the smoothness and waviness problems. NASA Langley has recently tested the Bellanca Skyrocket II, shown in Figure 4 for laminar flow. The airplane is of composite honeycomb construction and incorporates one of the NACA laminar series airfoil sections (NACA 63_2-215). Approximately 35 percent laminar flow over the upper surface has been observed with documentation now in progress. In addition, NASA recently developed a new series of natural laminar flow airfoils which have a negligible change in maximum lift between laminar and turbulent conditions. The issues with laminar flow still to be resolved include the practicality in light of bugs collecting on the wing and causing transition, the operation in clouds and weather, incorporation of de-icing systems that maintain the proper wing surface conditions, and the ability to design high performance laminar flow wings that need no leading-edge devices for good stall characteristics.

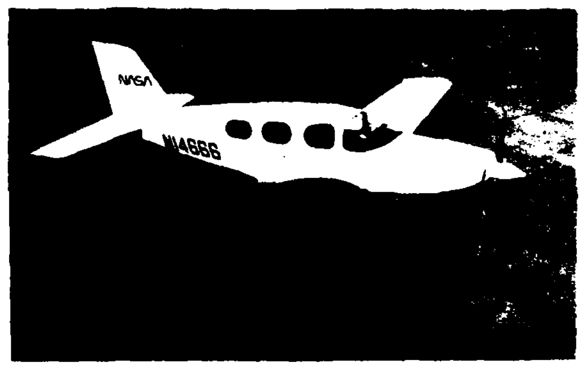


Figure 4. Photograph of Bellanca Skyrocket II.

The point of this discussion is that technology will permit the design of a very fuel efficient high performance single-engine airplane. If the market for this class of airplane exists, it will likely be in the business arena where company executives which are not full-time pilots will be at the controls. The single-piloted airplane will be expected to cope with the same weather conditions that confront the airlines but with much less flight time and flight proficiency. There is an urgent need for real-time weather information in the cockpit and for improved displays that will improve situation awareness. There are a multitude of gadgets available today that tell the pilot when he is right side up and pointed toward his destination. To integrate this information into a cockpit that will ease the task of assimilating the data without unaffordable amount of proficiency training is a challenge for the industry. Integrated CRT displays have been used for years in the military and are now showing up in the civil transports such as the Boeing 757 and 767. The benefits of this technology, I feel, warrant its early con-

sideration in the general aviation business fleet.

With airline deregulation a reality, commuter aircraft sales are experiencing rapid growth. Initially this growth is coming from existing airplane designs. NASA and the industry are working to build a technology base that will permit new designs which will be significantly more fuel efficient and that provide better ride comfort at a cost affordable to the manufacturer. Some candidate technologies being research include nonconventional configurations, composites, advanced turboprops, and active flight control systems. An artist's concept of an advanced commuter aircraft is shown in Figure 5. The most significant impact of meteorology on the design of aircraft for this application will be the turbulence environment and its effect on fatigue life and ride comfort. Most existing commuter aircraft were designed to comply with Federal Air Regulation, Part 23, which does not require fatigue analysis and testing. New commuters will comply with Part 25, which does address fatigue. The large transport industry has lived with fatigue analysis for many years.

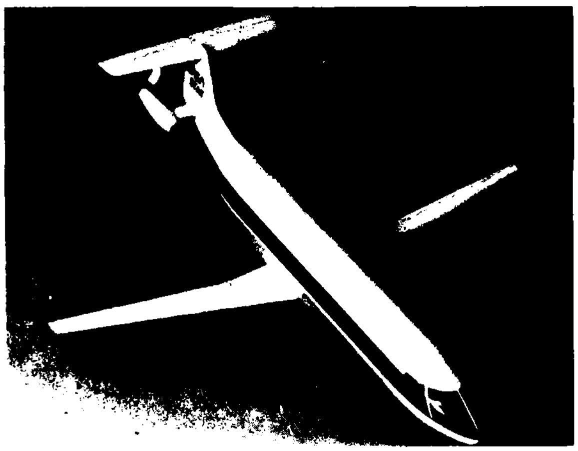


Figure 5. Photograph of advanced commuter aircraft model.

Figure 6 compares the turbulence or gust accelerations measured for two small jet transport operation. The frequency of encounter for a given acceleration is on the order of magnitude higher for the commuter than for the jet transport. While the lighter wing loading of the commuter can account for a portion of this difference (on the order of a factor of 2), the major difference is in the time spent in the lower and more turbulent atmosphere. I would note that the turbulence environment for typical commuter operations is one that needs better definition. The higher exposure to turbulence upsets will probably dictate the need for some form of active gust alleviation system.

The last meteorological impact that I will discuss is generic and will likely affect all aircraft classes. It concerns the design for pro-

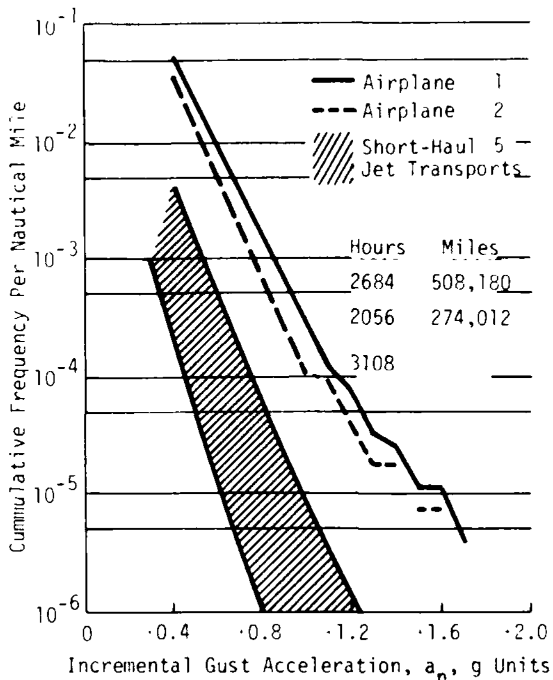


Figure 6. Comparison of commuter gust acceleration experience with range for short-haul turbojet transports.

tection of the aircraft and systems from lightning or electromagnetic effects. Techniques for protecting composite structures are known and should pose no major problem. It has been generally accepted that aluminum aircraft construction provides a good deal of protection for the avionic systems on-board. Composite construction will remove some of this protection. As avionic systems move into more flight control roles and exploit the use of micro-electronics, lightning protection will become more critical. NASA has recently entered a cooperative program with the National Severe Storms Laboratory to characterize the in-flight lightning strike. Last year the F-106 lightning testbed received ten strikes during operations in Oklahoma and Virginia. This program will continue over the next several years to acquire a data base engineers can use for design.

In summary, meteorology will impact future aircraft designs. Turbulence and gusts will affect design and operation of Ultralight and very low-wing loading airplanes that may comprise a large part of the sport and pleasure flying fleet. Business aircraft will be high performance and high flying, and will cope with all the weather conditions of the transport industry, but with a single and likely less proficient pilot. The turbulence environment for commuter aircraft will be more severe than that for current jet transports, and finally, lightning protection is a major concern for all future aircraft as more composites are introduced and micro-electronics are employed in flight critical systems.

SOME GUST RESEARCH PROBLEMS OF THE NEXT FEW YEARS

John C. Houbolt

NASA/Langley Research Center

I'm going to talk in a restricted vein, particularly about gust problems that might be more of the research nature in the next few years.

Listed in Table 1 are some of the gust problems that may be of concern in the next few years, again restricting attention to problems associated with aircraft design. The first item is a reminder of the wind shear work that is underway. We'll continue to try to understand it better and update work on it as we proceed into the next several years.

The second item deals with large aircraft. I've tried to depict here the so-called Boeing spanloader; notice the size is on the order of a 400 foot wing span. Airplanes of this type are of interest because of possible improved efficiency of flight, particularly with respect to fuel savings. Although such concepts may offer improved fuel economy, I wonder if atmospheric turbulence might not prevent them from becoming a reality. My feeling is that we probably can't design such aircraft practically because of the turbulence loads problems. Thus, we need to study the turbulence response problems of these aircraft rather carefully.

Item three depicts the concept that is introduced from time to time of flying aircraft together in side-by-side formation, either in near contact or in actual contact with one another. The primary notion of this scheme is of course to greatly increase the L/D of flight. Again, as with the spanloader configuration, I think the key problem of this arrangement is the gust encounter problem. My feeling is that turbulence will preclude routine operation of this coupled scheme.

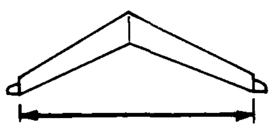
Items four through nine in Table 1 are mainly reminders of the gust problems we probably will be considering in the next few years. As Joe has already mentioned, we will continue to explore the use of gust alleviation devices. The idea of gust alleviation is a recurring notion, and actually quite a number of aircraft with gust alleviation devices have been tested, dating back to 1930. A more recent example is the very extensive gust alleviation program carried out on the B-52 airplane. A general approach in the consideration of gust alleviation has been to make use of existing control surfaces such as the flaps, stabilizers, and rudders, but this approach creates a primary problem. The use of existing control surfaces is not necessarily the best way to achieve alleviation. Some loads may be alleviated but at the expense of increased loads elsewhere. Actuators may be cumbersome and of limited capability. Gust alleviation, in a pure sense, should embody control surfaces which

TABLE 1

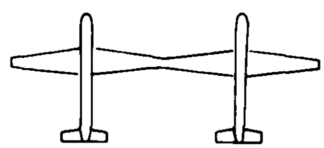
LIKELY GUST STUDIES DURING THE NEXT SEVERAL YEARS

1. WIND SHEAR WORK WILL CONTINUE

2. LARGE AIRCRAFT



3. "COUPLED" AIRCRAFT



4. GUST ALLEVIATION
5. SPANWISE VARIATIONS
   a.) B-57
   b.) Roll
   c.) Bending Moments
   d.) Recognition that N_o (zero crossings) problem is solved
6. MORE RECOGNITION OF PITCH (Obviate scale L problem)
7. BETTER SIMULATOR INPUTS
8. DATA GATHERING PROGRAM CONTINUES
9. CONTINUED UPDATED UNDERSTANDING OF TURBULENCE NEAR THUNDERSTORMS

test control loads and motion in an overall integrated sense, but designers are not quite willing to face the problem as yet in this sense. There are, of course, isolated cases where gust alleviation devices are currently being used in a limited sense. Our modern 747 and 1011, for example, use yaw dampers to dampen out lateral oscillations of the tail. In general, as we continue to develop better sensors and as we relax more our restrictions on what control surfaces to use, we will find increasing break-throughs in gust alleviation devices. I am sure.

Item 5, spanwise variations, relates to our characterization and consideration of atmospheric turbulence in an improved and refined sense. Over the years, it has been common in aircraft design to make the assumption that gusts are uniform in the spanwise direction. We've mentioned this fact in previous meetings. In reality the gusts are quite random in the spanwise direction, just as they are in the direction of flight. The roll response of an airplane in turbulence tells us this quite vividly. We've all experienced an airplane suddenly being tossed in a 20- to 30-degree attitude, thus, reflecting the spanwise gust variation. We've studied these spanwise effects analytically and have come to understand them quite well, but our experimental study of the problem is very limited. For this reason, we hope to use the B-57 airplane as a probe to study these detailed but important effects more thoroughly.

Associated with the spanwise gust effects is the so-called N_0 or zero-crossings problem; that is, the number of times per second the 1-g load level is crossed while in turbulence encounter. With the uniform spanwise gusts assumption, analytical evaluation of N_0 yields values which are unrealistically large. We have shown that if you take into account the spanwise variations, quite realistic values of N_0 are obtained. This fact hasn't been widely recognized as yet, but as we continue with our efforts, more and more people will become aware of these findings.

With respect to the design of aircraft to gusts, it is interesting to note that we still make use of the discrete gust concept using the simplest of assumption--the airplane is a point mass; it moves vertically only; the gust is discrete and is uniform in the spanwise direction. Oddly, the significance or importance of pitch is not very well recognized. When we consider the response or an airplane to continuous turbulence, one of the inputs is a parameter called L, the integral scale of turbulence which is a measure of the average eddy size of the turbulence. If airplane pitch is neglected, we find that the response depends very markedly on what scale value L is chosen. This dependence poses a problem since there is a question as to what scale value should be used. The question of scale value is in fact a big controversy. By contrast, if we include airplane pitch in the response evaluations, we find that the response becomes essentially independent of the scale value. This result is also not widely recognized but is quite significant since it obviates the need to consider one of the input parameters and especially one over which there is much controversy. As with the solutions to the N_0 problem, we must make more and more people aware of the importance of pitch in airplane response studies.

Item 7 was touched upon earlier in the fine talk we heard on simulators. My comments deal specifically with moving base simulators. Often in the use of these simulators, turbulence is included as an input. Invariably, however, the pilots observe or complain that the turbulence response they feel doesn't seem realistic. The general course of action then is to vary the nature of the turbulence input and the intensity until the pilot finds it acceptable. The reason the turbulence doesn't feel realistic, however, is due to the fact that the proper inputs are not used. In general, the airplane not only reacts to the vertical force produced by the turbulence, but reacts also to pitching, yawing, and rolling moments that are induced as well. There is little hope of making the repsonse feel realistic if, say, only the vertical force is included. We have developed means for simulating the various inputs, and I think we will see an increased recognition of the significance of these inputs and more attention being given to include the various inputs in future simulator studies.

In previous meetings, you heard presentations by Norm Crabill on the new gust data-gathering programs. We are hopeful that this program will continue to exist. As Norm described to you, with the measurement of 50 to 70 quantities, the amount of information being gathered is rather staggering. The hope, too, is that eventually we will be able to process nearly all of the data on-board.

As a final item, we will continue to update our understanding of turbulence near and in thunderstorms. We've discussed this subject in the past several years, and the outlook is that we will continue to do so in the next few years.

This, then, has been a short review of some of the research and analytical problems that we will face in the next few years on the problems of aircraft encountering atmospheric turbulence. Thank you and I see that Joe is now ready to answer questions.

Question and Answer Discussion

Robbie Robertson, ALPA: In the new generation aircraft 757 and 767 particularly, we're getting into more neutrally stable airplanes with a much lower tail loading, so the stability curve is far different than anything we've looked at. In reference to one comment you had up there about the effect of pitch, are we getting into an area, or will we get into an area where the classic gust equation (which has been the design criteria for so many years) will be affected more severely because of the decreases in the stability of the airplanes due to small tails? It's just inter-

esting to me that we're seeing these come down the line, and based on your research, could we see further problems down the line in terms of fatigue?

John Houbolt: With respect to these new aircraft where we get into smaller and smaller tails or the use of active controls, we will run into additional problems, particularly with design of active control systems where the problems of reliability, safety, power requirements, accuators, and this sort of thing are encountered. That is going to be the real problem, and it will bring in these other degrees of freedom to a greater extent. Just how much its going to effect the fatigue life, we don't know yet. It's something we have to keep our eyes open to. I don't think it is going to effect the structural strength too much but be more manifest in problems such as fatigue as you mentioned there.

METEOROLOGY IMPACT ON ATC SYSTEM DESIGN

Frank E. Van Demark

FAA/Systems Research and Development Division

The impact of meteorology on Air Traffic Control (ATC) system design provides a very broad basis for discussion, for designs, and for cost benefit evaluations. The myriad of choices for implementation is a problem of great magnitude, given the economic climate of today. Cost versus benefit has always been a factor but now requires greater emphasis.

Before expanding on FAA's views, let me begin by presenting the FAA area of jurisdiction and concern. FAA's mission is the safe and efficient use of the U.S. national airspace. The National Airspace System (NAS) is composed of: (1) diverse users; (2) air traffic controllers/flight service specialists; (3) hardware/software systems for communication, navigation and air traffic control; and (4) procedures for all to follow. The impact of meteorology on system design is extremely complex and sensitive to views of the users (pilots, airport managers, fixed base of operators, etc.) and the Agency's operations.

My division, the Systems Development Division, is responsible for FAA's R&D weather program and FSS automated/pilot self briefing.

Within the resources allocated to weather this FY and next and based on our assessment of FAA systems utility and user demands, we have decided to concentrate on expanding and improving weather data acquisition, increasing the speed of weather data transmission and automating those actions that lend themselves to standardization for automated data processing. Our efforts are generally divided into three programs - automated weather observations, weather radar and improvements to the national airspace system as related to the handling of weather data and products.

We are most concerned in providing timely advisories of hazardous weather. To be meaningful, these advisories must be relevant to the user's location in the national airspace and point in time. However, the reports are derived from various sources such as surface observations, pilot reports, weather radars, ATC radars, weather satellites, etc. The data must pass through many hands and many procedural actions, and there is always the one-on-one pilot/controller information transfer problem when extra pressures on both jobs interfere with weather data dissemination. Timely weather advisories are no easy task.

In all areas our primary thrust is to adapt current and new ATC systems to better satisfy user requirements for weather products. In the case of the Next Generation Weather Radar (NEXRAD), Terminal Weather Radar, and Automated Weather Observation System (AWOS), we are devoting resources specifically related to weather. For the balance of this presentation, we will discuss systems that are ready for or under consideration for implementation, and where research and development investments are now being made. The long-term impact of these investments includes consolidation of facilities, personnel efficiencies, and centralization of functions. FAA will be better able to meet greater demands for preflight and in-flight weather guidance and provide faster service with no increase in people. Pilots, controllers, and specialists will all benefit.

Current and Planned Programs Involving Meteorology

Systems under or nearly ready for implementation include: En Route Weather Display System (EWEDS), Leased Service A Equipment for FSSs and Center Weather Service Unit (CWSU), Automation for Flight Service Station specialists, Pilot Self Briefing via Interim Voice Response System (IVRS), National Airspace Digital Information Network (NADIN), Aviation Route Forecast (ARF) for FSSs and pilots, Pilot Self Briefing via FSS Automation (using computer terminals, voice recognition, and computer generated voice output), Display of Hazardous Weather on the Center Controller's Plan View Display (PVD), Modular Automatic Weather Sensor System, Computer Generated Automatic Terminal Information Service (ATIS) for pilots and replacement of our weather switch in Kansas City.

EWEDS

The En Route Weather Display System is a faster scan weather depiction system which can be linked to a maximum of twelve weather and surveillance radars per center for the display of analog reflectivity information. The system generates weather contours, radar status, alphanumeric, symbolic, and map data properly positioned on color displays which are to be located at CWSU and EFAS and later for all ATC radar positions. Test and evaluation at Cleveland and Atlanta Centers has been led into the procurement of radar display off-centering and mosaicing.

Operational tests at Cleveland begin very soon and continue for a period of six months. Assuming all goes well, implementation of EWEDS should begin nationwide in January 1982. The results of using EWEDS will be evident to users in the timeliness and quality of hazardous weather advisories.

Leased Service A Equipment for the CWSU

Leased Service A equipment like that for our FSSs is planned for the CWSUs. These systems will provide the needed capability for a fast, reliable means of putting CWSU generated messages on Service A and also the ability to receive national weather data at high speed. Each CWSU will be provided with two control units, two video display units, and two printers. The meteorologist may also make requests to the Weather Message Switching Center in Kansas City utilizing

the request/replay capability to obtain additional data for improved forecasts.

Automation for FSS Specialists

The Leased Service A (LSA) equipment at the FSSs is only a preview of the full automation that the FSS specialist will have with the inception of the Flight Service Automation System (FSAS).

Leased Service A was one of our hard choices. We recognized the need to speed up weather data transmissions to the FSSs. During the periods of bad weather across the country, these were provided when the low speed system could not get all the data to each FSS in the update period. Based on work done by air traffic with Western Union at DuPage FSS, we knew we could acquire a high speed capability via lease arrangements with the operational device in place far faster than via our ongoing buy program. The choice was made in the face of comments that now FAA does not now need its $200M FSS automation. Fortunately, we were able to continue our logic of leasing an interim service to meet a critical need while continuing the FSS automation program.

While the LSA provides high speed access to weather data, the buy program will provide the specialist with a more flexible weather briefing capability including graphics, flight plan filing, and system capacity for 1995. In addition, an initial pilot self briefing via computer terminals will permit direct access to the same data base used by the FSS specialists. The impact of this system will enable FAA to consolidate Flight Service Stations into centralized locations for greater personnel and facility efficiency.

Pilot Self Briefing via Interim Voice Response System (IVRS)

The FSS Automation Program will also provide a computer-controlled voice response system (VRS) and direct user access to the computer system via telephone and communications terminals. However, this phase will not be operational until the mid-1980's.

Presently functioning in a test/public demonstration configuration in the Washington, DC and Columbus, Ohio areas, is a VRS which enables pilots to receive an automated, limited, weather briefing by using a Touch-Tone^R telephone-to-computer circuit. A computer-generated voice responds to the push-button signals and provides selected Surface Observations, Terminal Forecasts, Forecast Winds Aloft for specific en route locations, Convective SIGMETS, and Alert Weather Watch. Acoustically-coupled tone signalling devices that generate Touch-Tone^R signals can also be used to access the VRS over non-push-button telephones. The user is unaware of the fact that the data base is automatically updated on the fly as new data becomes available.

Recognizing the effectiveness of the test VRS as a means to input and receive information without having to contact an FSS specialist, the FAA is actively pursuing installation of an interim VRS. Also, the first test/public demonstration of automated flight plan filing, utilizing Touch-Tone^R VRS, is scheduled to be conducted in the Windsor Locks, Connecticut area during the latter part of 1981. A major impact of the VRS will be the offsetting of demand growth on FSS operation as well as faster service to pilots.

Implementation of VRS on an interim basis like Leased Service A is another hard choice that will create opinions against continuing the multi-million dollar FSS/Pilot Self Briefing program. As before, the interim measure is to gain a limited service quickly.

National Airspace Data Interchange Network (NADIN)

The current FAA data communications capability is characterized by the use of a number of separate independent dedicated networks subject to rate increases and circuit use inefficiencies. A contract is now underway to combine these separate networks into a single network, NADIN, which will meet the varied needs of present FAA operations and provide capacity for growth to accomodate future requirements as they develop. NADIN will be a high capacity, high speed (9600 baud initial backbone rate) national circuit with reliability characteristics commensurate with those required throughout the NAS environment (99.9 percent reliability for backbones system with complete error detection and correction).

NADIN network configuration requires two message switching centers: one located in Atlanta, Georgia; the other at Salt Lake City, Utah, and 23 data concentrators-one located with each ARTCC, including Anchorage, Honolulu, and San Juan. The NADIN system will accept messages from originating stations, store them, and transmit data to addressees. The concentrators also provide code and speed compatibility required for the variety of terminal devices and will compact all traffic for efficient use of trunk facilities. The impact of this system will be increased efficiently due to use of high speed equipment.

Aviation Route Forecasts (ARF)

ARF is a computer generated detailed aviation forecast via high speed communications link for specific routes requested by pilots. It is a joint FAA/National Weather Service effort. All information required for the forecasts is placed in the computer in grid form. The system will provide viewable, quantified area type weather data, route oriented aviation forecasts, and other flight planning data such as NOTAMS (Notices to Airmen), PIREPs, density altitudes, etc. The program is jointly supported by FAA and NWS as affording system operational efficiencies to both organizations. It is also a very key element to Pilot Self Briefing via terminals and VRS.

Pilot Self Briefing via FSS Automation

The VRS mentioned previously is not the only automated weather briefing/flight plan entry

method being developed by the FAA. Commercially available terminals with the capability to provide pilots with a visual display, hard-copy, or both can be used to access our FSS computers. The Windsor Locks, Connecticut area test/public demonstration also mentioned previously will include such terminal devices, and it is envisioned that home computers or devices utilizing television sets for displays, not unlike the NWS Green Thumb, will eventually extend PSBT capability into user homes and offices.

Regardless of the method utilized, each will ultimately enable pilots to obtain a weather briefing and enter a routine flight plan into a computer without the assistance of a flight speciallist. The computer will review the flight plan data entered and indicate any errors. The corrected plan will then be forwarded to its proper destination.

This program feature has gained the FSS automation program the highest of priorities in DOT programs. Over the next fifteen years, we anticipate a 1.5 billion cost avoidance due to Pilot Self Briefings.

Display Hazardous Weather on the Center Controller's PVD

We have developed the capability to automatically access weather radar data, have a meteorologist annotate it, if necessary, and provide it for two levels of intensity display on air traffic control Plan View Displays (PVD). Until recently, this feature was considered for long-term implementation due to problems of computer system capacity in our en route ATC systems. However, it now appears technically feasible to enter the contour information directly into the PVD via a radar data processor under control of the CWSU. The impact of this system is to give the controller much more reliable information for use in routing aircraft away from the most hazardous weather areas. While EWEDS provides a similar [illegible], a common display alleviates the frustration of [illegible] correlations ([illegible] and weather).

Modular Automatic Weather Sensor Systems

In a joint FAA/NWS program, we have developed a basic automated system that provides automatic sensing and reporting via computer generated voice the temperature, dew point, wind, altimeter, and density altitude. The system is identified as Wind, Altimeter, and Voice Equipment (WAVE). Sixteen WAVE systems were funded for procurement and installation in FY 1981.

The design is modular, permitting up-grading to more complex systems by adding additional sensors and processing. Follow-on systems are called Automated Low-Cost Weather Observation Systems (ALWOS), which include all the WAVE functions plus single sensor measurement of ceiling, visibility, and some basic present weather sensing. The FAA began testing an ALWOS at Dulles International Airport in October 1980. A similar ALWOS adapted to oil rig environment will be operationally tested on an offshore oil platform starting this month.

Concurrent with these ALWOS tests, we are evaluating several visibility and cloud height sensors at Arcata, California. Visibility measurements include surface ranges of up to six miles and cloud height measurements up to 5,000 feet. FAA and the Air Force are also conducting visibility tests at Otis Air Force Base, Massachusetts. Again, we have hard choices to make. Another joint program with Department of Defense and Department of Commerce is to address common procurement of automated aviation observation systems. A panel of experts have assessed the total requirements picture and determined, e.g., CHI over 5,000 feet are required by Department of Defense and Department of Commerce. We have decided we must proceed with a 5,000 feet CHI since airport sponsors under ADAP funding have only the expressed need of general aviation to provide weather observation at satellite or releaves airports at up to 5,000 feet.

In addition, tests will be conducted in early 1981 involving present weather sensing to be added to the Dulles ALWOS along with multiceiling and visibility sensors. With the addition of these functions, the more complex system will be identified as the Automated Weather Observation System (AWOS).

Computer Generated Automatic Terminal Information Service (CG ATIS)

At present, the manually derived data and recording provides non-control operational and meteorological information in the terminal area via a 3-minute tape recording. We have developed a system providing computer generated voice and automatically derived data and ATC inserted messages. The system is under test at Buffalo, New York. Output from weather sensors is fed to a computer that converts the parameters to voice which are then transmitted through a VOR or other radio frequency to aircraft in the area. Commercially available systems have already been employed at non-ATC airports. FAA is currently working out the procedure problems for ATIS use at FAA controlled airports. This same technology is also applicable to automation of TWEB and PATWAS.

Next Let's go to:

Research and development efforts now underway which include application and display of Doppler weather radar for en route and terminal air traffic control; concentration of FAA's weather data management in FSS and CWSU automation; automated reporting of weather data from aircraft in flight; weather data communications to aircraft-via Discrete Address Beacon System (DABS), and via communications links on NAVAIDS; weather data handling via the en route ATC of the 1990's; and automated detection, tracking and prediction of hazardous convective weather.

Doppler Radar Application

Development of a Next Generation Doppler weather

Radar (NEXRAD) is being pursued jointly by the NWS, the USAF (Air Force Geophysics Laboratory and Air Weather Service), and the FAA for establishing a national weather radar network to meet common weather data requirements. However, ATC terminal weather requirements in terms of coverage, data rate, resolution, accuracy, and false alarm rate of weather information are substantially more demanding than those identified by other participating agencies and are being further investigated by the FAA.

Our ongoing program efforts include the assembly of an experimental Doppler Weather Radar transportable test bed at the FAA Technical Center; turbulence measuring test flights at the Technical Center and at the National Severe Storms Laboratory to determine correlation between aircraft and radar data and data analysis by Lincoln Laboratory. We are also participating with NOAA and National Science Foundation in an effort this summer directed to gaining more knowledge of severe weather impacts on ATC operations.

Lincoln Laboratory is also investigating the ability of NEXRAD type radars to meet ATC weather requirements especially the more demanding terminal area requirements.

Concentration of FAA's Weather Data Management in FSS and CWSU Automation

FAA's weather data bases will be at two centralized sites (Atlanta and Salt Lake City) and distributed to twenty-three Flight Service Data Processsing Systems (FSDPS) located ATC centers. These Center-located computers will distribute the data to 61 consolidated/automated Flight Service Stations. The intent is to focalize all FAA's weather data management in these facilities and from them service en route and terminal ATCs as well as FAA's flight information service of which FSSs are the backbone. The impact here is faster service and less duplication of effort.

Automated Aircraft Reporting

Expansion of our weather data base through onboard weather sensors and automated data collection/dissemination would be of immeasureable value. However, costs of data collection, processing relative to space positioning and determination of relative value for ATC advisories has no obvious design conclusion. From my vantage point, I would want NOAA to improve its data base via whatever means and issue reports for aviation use based on the best sources of data. I am not convinced that FAA should be directly involved at this time. The increase in the upper air data base for improved route wind forecasts is obvious. Impact on the ATC system could include real-time metering and spacing of aircraft, profile descents, reduced fuel consumption, and increased efficiency.

Communication with Aircraft

Currently, controllers send and receive all information through voice radio communication with aircraft. Frequency utilization is strained at times and although additions are possible, the Agency cannot continually add controllers for one-on-one communications. Discrete Address Beacon System (DABS) Data Link is being tested as an aid and supplement.

In the long-term, DABS will be available to provide rapid nonvoice communication between the ARTCC and aircraft. Many routine and high priority messages will be transmitted via Data Link. Those weather related items will include; hazardous weather advisories, routine weather data upon request, route-oriented weather, and downlinked weather. The impact here is increased pilot awareness, safety, and less involvement of the controllers.

Our mission also includes airborne service to general aviation nationwide. DABS will be nationwide in time, but economics and airspace coverage will dictate alternative communications links to serve this purpose. We are actively applying current technology to communicate digital radar data and weather data voice messages to cockpit devices to speak or display information automatically, i.e., without the one-on-one people operation.

Aviation Weather Collection, Processing, Dissemination, and Display via En Route ATC of the 1990's

Currently, the collection, processing, and dissemination of aviation weather is partially integrated within the ARTCC through the ARTCC's CWSU (Center Weather Service Unit). CWSUs are located in all ARTCCs to provide a consolidation of weather services. They are the focal point for real-time collection, monitoring, interpretation, and dissemination of hazardous weather information. The CWSU meteorologist provides general weather briefings and hazardous weather advisories to the controllers, and collects, interprets, and disseminates PIREPs. Present CWSU equipment includes a Controller Plan View-Display, two Weather Bureau Remote Radar (WBRR) recorders, a facsimile machine, a Geostationary Operational Environmental Satellite (GOES) photo recorder, a Service "A" teletypewriter drop, and telephones and interphone service. The addition of EWEDS and leased Service A will be a major upgrading of the CWSU. The long-term impact, including three-dimensional weather data from NEXRAD sites, supplemented by other weather observations obtained through NADIN, will vastly improve the CWSUs' effectiveness.

We have underway other projects directed to weather on new ATC en route and terminal display subsystems - ETABS and TIDS. These subsystems are in our long-range plans. This time we are preparing for test and evaluation to demonstrate to our ATC personnel how these new systems will address operational requirements. We will conduct these efforts at Atlantic City. Field personnel will be called into participate. The end result is a cross section of opinions/reactions leading to system developments having a greater assurance of operational acceptance, a factor FAA considers of primary importance.

Automatic Cell Detection and Tracking

Weather radars currently used for precipitation observation by the National Weather Service require manual and labor intensive interpretation to provide user desired products, e.g., the radar data are displayed as contour maps of reflectivity and must be subjectively analyzed to deduce regions of possible hazard.

Recent advances in weather radar system design include the application of digital data processing to data management, processing for display, transmission to remote displays, and archiving. Color displays readily show the reflectivity of an individual resolution element of the radar system and color is easier to read than the earlier gray shade coded displays. The analysis of the picture to provide the required hazard detection, warning, and forecast which has been manual will be replaced by a computer based data processing scheme using digital output from a weather radar system. The scheme is to automatically detect regions of possible hazard and provide short range (0-20 minutes) forecasts of storm development and cell motion. It is currently being tested and will be available for implementation by the mid 1980's. The impact resulting from automation of radar analysis and forecasting will be greater forecast accuracy and increased airspace efficiency.

Summary

In summary, the impact of meteorology on air traffic control and the National Airspace System design is one of hard choice in the real world of today's economics balanced by technical feasibility and FAA's operational needs. Our desire is to provide the users with the most responsive advice as to the weather situation. In turn, we expect the user to be a cooperative entity, and together we will do the fantastic. The world has come to expect this from the USA air traffic control system.

OZONE AND AIRCRAFT OPERATIONS

Porter J. Perkins

NASA/Lewis Research Center

Introduction

Ozone in the upper atmosphere has been of concern to aircraft operators both from the standpoint of its effect on aircraft operations and the effect of aircraft operations on it. High concentrations of ozone in the cabin of some flights operating at high altitudes have caused physical discomfort to both flight crews and passengers. Concern for this problem has resulted in FAA regulations (to be imposed in 1982) limiting the concentrations of ozone in the cabin. On the other hand, the depletion of ozone by emissions of high altitude jet aircraft has also been of concern. Investigations of this problem are still not well defined. Other potential causes for possible depletion of the ozone layer such as flurocarbons from aeorsol cans are also being studied.

This paper will concentrate primarily on the cabin ozone problem with only a brief summary of the predictions of the effects of jet engine emissions on the ozone layer. Cabin ozone will be discussed in terms of health effects, the characteristics of ozone encounters by aircraft, a brief history of studies to define the problem, corrective actions that have been taken, and possible future courses of action that may be taken. Such actions could include avoiding high ozone concentrations by applying ozone forecasting in flight planning procedures. This appears to be an appropriate issue for discussion at this workshop.

The Cabin Ozone Problem

Is ozone a problem? Ozone is an extremely toxic gas in terms of the low level of concentrations that produce adverse health effects. Thus, it becomes a problem when relatively high concentrations are encountered in flight. However, climatological data indicate that a large majority of flights are conducted at latitudes, altitudes, and conditions such that ozone exposure is not a problem.

Can the ozone problem be solved? Ozone can be destroyed by heat, surface contact, and scrubbers. These are flight proven solutions demonstrated by both laboratory and flight hardware. The question, therefore, is not if it can be done, but how can hardware fixes be accomplished most economically. This is a particularly important consideration since high ozone is encountered only at certain times and locations; and therefore, the destruct hardware is needed only occasionally. The weight penalty must be held to a minimum.

Areas of high ozone can be avoided, if known. Flight at or below the tropopause will clear areas of high ozone. However, operations below the optimum flight altitude impose rather large fuel penalties. Thus, the precise spacial and temporal location of high ozone areas must be determined in advance to minimize these penalties. Ozone forecasting for flight planning purposes is yet to be developed and proven.

Much has been done in the past several years in defining the cabin ozone problem. Many health studies have been conducted on the effects of ozone, both for aircraft passengers and crew members and for the overall protection of public health as established in the Clean Air Act. Extensive atmospheric ozone measurements have been made. These include vertical and horizontal ozone profiles determined from balloon and aircraft measurements, and total ozone overburden measured by satellite and ground based instrumentation. From these long term measurements, the climatology of ozone is well defined.

Airframe companies have developed and improved ozone destruct hardware which has proven effective in flight. Installation, maintenance, and weight penalty are an added cost to flight operations. Thus, the goal of this workshop should be to explore the most cost effective approach to limit ozone concentrations in the cabin of high altitude aircraft.

Toxicity of Ozone

The health effects of ozone have been determined by organizations concerned with photochemical smog (considered to have the same effects as natural ozone) and by the FAA concerned specifically with the aircraft cabin problem. As to be expected, some people were found to be more reactive to ozone than others. Small concentrations can cause such symptoms as nasal dryness, cough, pain beneath the breastbone, headache, and a burning sensation in the throat. Serious effects occur at high concentrations. The following table was derived from a literature review reported by the FAA in one of their health studies (Higgins, et al. 1979).

TABLE 1

OZONE TOXICITY EFFECTS

Concentration (ppmv)	Effects
0.20 - 0.20	Biological threshold for normal people
0.30 - 0.50	(aggravated by exercise, noticeable symptoms)
0.30	Threshold for sedentary subjects
0.50	Dividing line between mild and serious effects
1.0 and above	Serious damage
(EPA Primary Ozone Standard - 0.12 ppm)	

Ozone Climatology

As noted earlier, ozone climatology is well defined and establishes the fact that for most flight operations high ozone is not a problem. It is of concern only during certain months, at higher latitudes, and at altitudes above the tropopause (*Haldeman and Nastrom, 1981*). *The* seasonal variation of mean atmospheric ozone at latitudes above 40°N is shown in Figure 1.

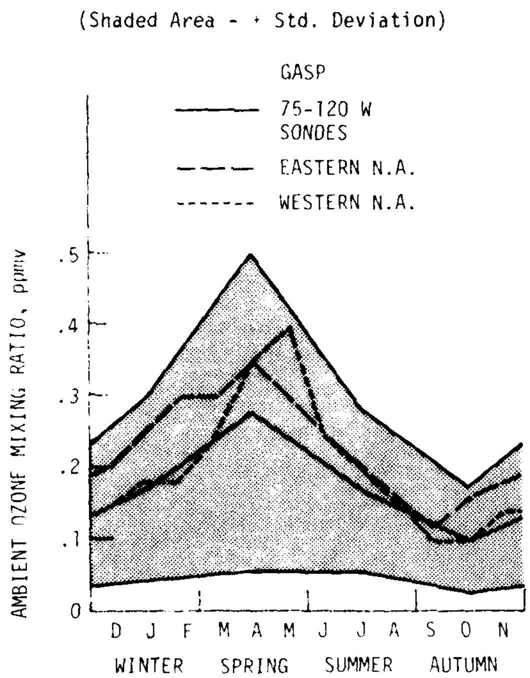


Figure 1. Seasonal variation of mean ambient *ozone* at 40-50 N and FL 370 for North America.

Ozone peaks during the spring months and is at a minimum in autumn. During the peak season, ozone increases from the equator poleward with a sharp increase starting about 30°. This is shown in Figure 2. Ozone is of little concern below the tropopause but increases rapidly with height above the tropopause as shown in Figure 3. Large variations in synoptic weather systems are primarily the cause of large standard deviations shown in Figure 1, 2, and 3 (shaded areas).

Characteristics of Ozone Encounters

In-flight measurements of outside and cabin ozone levels (see Figure 4) particularly from the NASA Global Air Sampling Program (GASP) have provided information for defining the characteristics of ozone encounters experienced by airline aircraft. Of interest are the maximum ambient concentrations that can be expected when *high* levels of ozone *are encountered* together with the duration and variability of such encounters. The frequency of high ozone levels *is very important* to know since statistics on

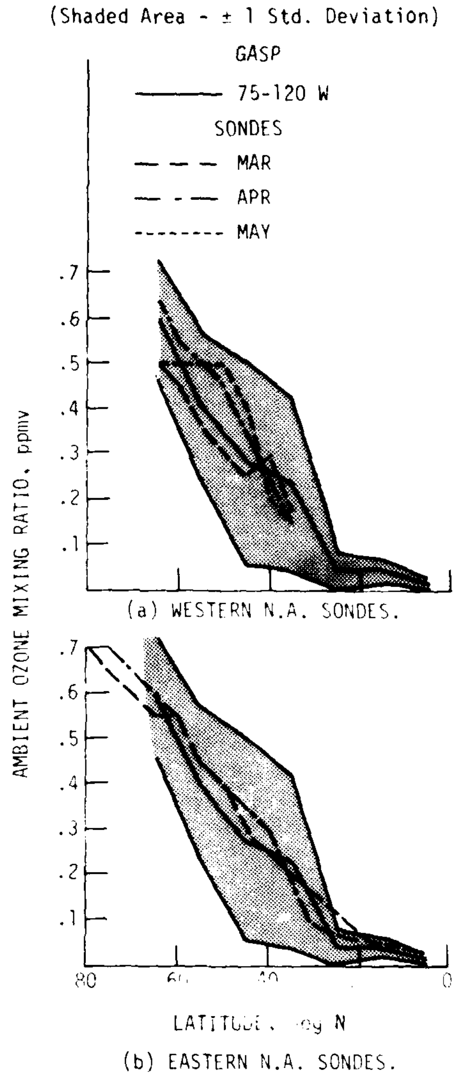


Figure 2. Meridional variation of North American ambient ozone levels at FL 370 in Spring.

the probability of encountering high ozone are written into the FAA regulations limiting ozone in the cabin.

An example of a high ozone concentration encounter is *shown in Figure* 5. *These data were* taken by GASP on a long haul flight of a 747SP from the Mid East to New York in the spring. The peak outside ozone reached 1.2 ppmv, a serious condition, if that level were in the cabin. Considerable varibility of the ozone level was experienced as *the flight progressed* westward. *Generally*, high concentration (above 0.3 ppmv) extended over a long distance as the *flight path remained* above 50°N latitude.

An example of ozone measurement statistics derived from routine airline operations of a 747-

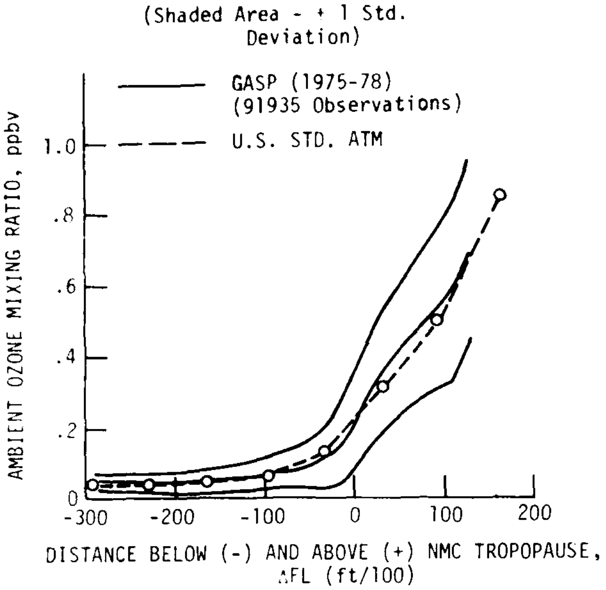


Figure 3. Ambient ozone mixing ratios with respect to the tropopause.

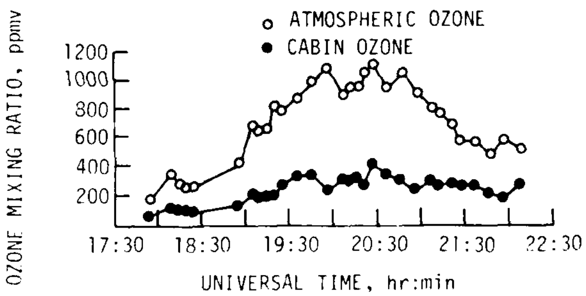


Figure 4. Time history of ambient and cabin levels for B747-100 airliner flying from New York to Los Angeles on April 3, 1977.

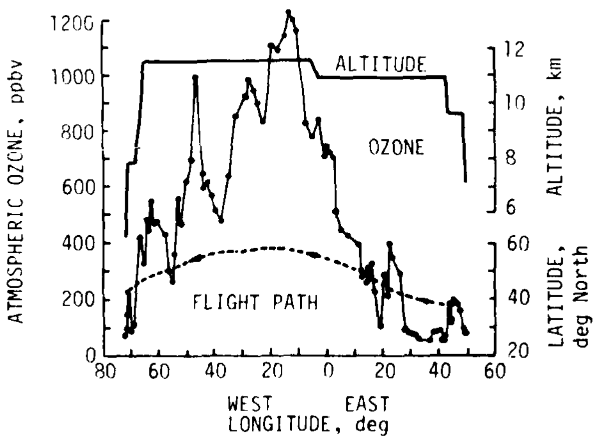


Figure 5. Example of a high ozone concentration encounter.

100 for one year over the United States is shown in Figure 6. As noted previously, this plot shows that the highest ozone can be expected in the spring and the lowest in the fall. On a yearly basis, about 10 percent of the measurements exceeded 0.3 ppmv. It should be pointed out that this plot should not be used to determine the probability of encountering a given ozone level for a complete flight since each ozone measurement plotted here is not an independent observation.

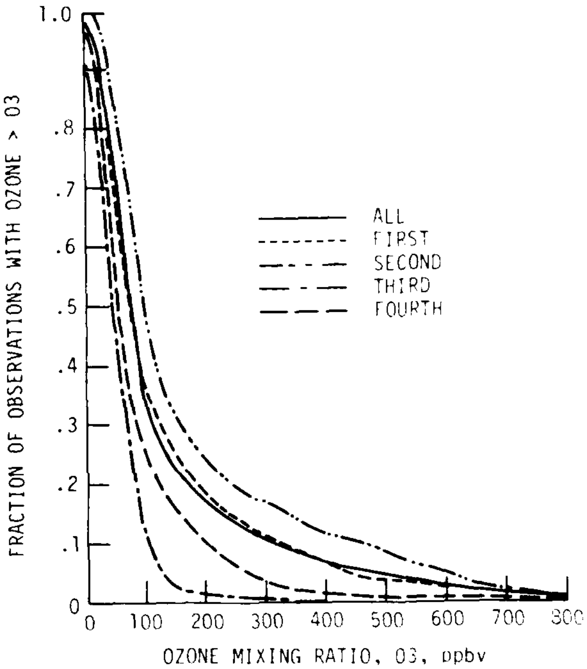


Figure 6. Cumulative ambient ozone frequency distribution for B747-100 for one year.

History of Cabin Ozone Problem

High ozone levels in the cabin of high altitude jet aircraft was recognized as a potential health problem at the beginning of the jet age when people began to smell ozone. The FAA conducted a survey in 1961 (Brabets, 1963) in which ozone measurements were taken in the cabin. No action was taken as a result of this study. The problem came to public attention when the long range 747SP airliner was introduced into service in 1976. The combination of extended flight time (over 12 hours), high latitude flight routes (New York to Tokyo), and lack of recirculation in the cabin of this aircraft caused unusually high ozone levels in the cabin for extended periods of time.

The physical discomfort experienced by passengers and crews (particularly flight attendants) led to a series of actions by the FAA to limit ozone concentrations in the cabin. An Advisor

Circular was issued in 1977 followed by an Advanced Notice of Proposed Rulemaking. In 1978 a Notice of Proposed Rulemaking was issued. During this period FAA personnel conducted cabin ozone measurements with portable instrumentation on several different airlines and types of aircraft to help define the problem with respect to routes and airline equipment. Also, studies of health effects as applied to aircraft passengers and crews were conducted by the FAA Civil Aeromedial Institute.

In 1980 a cabin ozone regulation was issued by the FAA limiting ozone in aircraft cabins (Federal Register, 1980). In abbreviated form this rule says:

> During flight above FL 180, not exceed 0.25 ppmv (sea level equivalent). In addition, for new designs (FAR Part 25) limit 0.10 ppmv (sea level equivalent) time-weighted average during any 3 hour interval. Also, for certificate holders (FAR Part 121) limit 0.10 ppmv (sea level equivalent) time-weighted average for schedule block times in excess of 4 hours. Compliance must be shown in Analysis-Statistics (with an 84 percent confidence limit) indicate will not exceed limit, or Tests - Control equipment will keep cabin below limits.

NASA has also been active in studying the ozone problem particularly in regard to ozone measurements both from aircraft and balloons. The NASA GASP produced a large quantity of aircraft measurements from 1975 through July 1979 both of ambient (outside) and cabin ozone much of which were simultaneous measurements (Perkins, et al., 1979). These data are directly applicable to the aircraft problem as compared to spot measurements by ozonesondes. NASA also conducted a symposium on ozone for the FAA and a workshop on the cabin ozone problem for all concerned in 1978 (NASA CP-2066, 1979). The workshop participants represented airline and airframe companies, equipment manufacturers, university and company research organizations, cabin crews, and government agencies (FAA and NASA). The findings and recommendations of these working groups included a better definition of the problem and assessment of solutions. Flight planning to avoid high ozone concentrations and ozone destruction techniques installed in cabin air systems were discussed.

The latest effort by NASA has been the use of satellite data from Nimbus 7 (Total Ozone Measurement Spectrometer (TOMS)) to locate, in real time areas of high ozone and utilize this information in flight planning. This approach will be evaluated during March and April 1981 in a cooperative effort between NASA and the airlines. Up to the present time, NASA has published over twelve reports or journal articles on the subject of cabin ozone.

Corrective Actions to Limit Ozone in the Cabin

Ozone destruction techniques were evaluated in flight on a 747 [illegible] to measure ozone [illegible] the cabin. The effectiveness of the [illegible] can be determined by the ratio of ozone in the cabin to that existing in the outside ambient air (ozone retention ratio). The results of three methods to reduce ozone in the cabin air system are shown along with the modifications in Table 2. The 747SP with no reduction technique had a high retention ratio ([illegible] percent). With modified cabin air circulation, this was reduced to 58 percent. Using high temperature inlet air from the fifteenth stage compressor, bleed destroyed most of the ozone coming into the cabin (19 percent retention). This is not a practical solution because of the high fuel penalty imposed by supplying cabin air from a higher pressure stage than necessary. A charcoal filter in the air ventilation system proved to be the most effective solution allowing only about 5 percent of the outside ozone to enter the cabin. The charcoal filter was replaced by much lighter weight catalyst materials which are now in use in some airline aircraft. Conversion kits using these materials are available for installation on many airliners.

TABLE 2.

CORRELATION OF ATMOSPHERIC OZONE CONCENTRATION AND IN-CABIN OZONE LEVEL [illegible] AIRLINERS

(Selective [illegible] with and without ozone destruction [illegible] in cabin air system)

Aircraft type	[illegible]	Ozone retention in cabin, percent of atmospheric level
B-747-1[illegible]	[illegible]	[illegible]
B-747-SP	none	[illegible]
	Modified cabin air circulation	58
	15th-stage compressor bleed	19
	Charcoal filter	5

Ozone avoidance techniques [illegible] to be the most economical solution [illegible] proven. The NASA workshop in 197[illegible] concluded that presently available data are sufficient to qualitatively define areas of high ozone. However, additional information is required for quantitative ozone forecasting needed for flight planning. Better tropopause height forecasts are needed since ozone forecasts will depend heavily on a more precise definition of tropopause height than are now given. Also, it was concluded that an operational ozone forecast model should be developed and verified. Total ozone satellite data available on an operation basis would help. Its usefulness may be deter-

mined from the NASA-Airline experiment noted above.

Future Efforts on Cabin Ozone

It appears for the majority of flights (domestic in particular), avoiding areas of high ozone using operations ozone forecasts is the most economical solution to the cabin ozone problem. However, the accuracy and reliability of ozone forecasting must be demonstrated and determined acceptable by the FAA. Satellite data may be the needed tool. This is yet to be determined and should be a future effort. The real-time correlation of TOMS data with cabin measurement now going on will help to assess this approach. Other ozone measurement programs both past and on-going should also be used for satellite correlations. Certainly a better definition of the tropopause height and type would be most valuable.

For flights above 40°N latitude, ozone destruct equipment should probably be used since high ozone occurs frequently in the spring months, and operations at low altitudes would impose high fuel penalty. Such equipment is available and is effective. Thus, it appears that no future effort in this area is required except perhaps to reduce weight and maintenance.

Destruction of Ozone Layer

The effect of jet engine emissions on the ozone layer has been controversial since the first studies in 1971. These early concerns prompted rather extensive studies during the last decade in stratospheric chemistry. As new knowledge became available, the magnitude of the calculated effects has varied considerably. Early predictions at the end of the extensive government sponsored Climate Impact Assessment Program in 1974 indicated that a fleet of SST aircraft would decrease the ozone column by about 4 percent. As revisions to chemical rate coefficients were determined in later years, the decrease was predicted to be less (-3 percent in 1976). Additional information available by 1978 reversed the prediction noting a possible 3 percent increase in ozone. The latest estimates (1980) again show a potential 4 percent decrease. It should be pointed out that all predictions were accompanied by significant uncertainties. Continued laborabory studies and more experimental data will help to reduce the uncertainties.

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SECTION IV
BANQUET PRESENTATION

EFFICIENCY IN FLIGHT

Ron Sessa

USAir

That was quite [illegible] guarantee you one thing that [illegible] speaker to that [illegible] find.

I'd like to [illegible] the Workshop Organization [illegible] invitation to be here tonight. [illegible] and I think it' [illegible] such a distinguished [illegible] the program and [illegible] here and what they [illegible] little nervous. There's [illegible] out there, and I was [illegible] together and make sure that [illegible] and all the issues. [illegible] do that, but I'm going to try [illegible] there in the middle [illegible]

I was asked [illegible] aviation efficiency. I don't [illegible] how that relates [illegible] I think that [illegible] that over pretty well [illegible] I also feel that I [illegible] working sessions [illegible] work, and so maybe the [illegible] and when I [illegible] afterwards, [illegible]

You know [illegible] gallon, efficiency [illegible] could get [illegible] were [illegible] we know it' [illegible] is the [illegible] your [illegible] pretty [illegible]

I'd [illegible] numbers. You know [illegible] the numbers I'm [illegible] that affect us at [illegible] fuel. I think [illegible] well express the magnitude [illegible] of the scale of the [illegible] flight efficiency is, and [illegible] discuss what is being done [illegible] doing it. There are manufacturers [illegible] it, the airlines, the government, [illegible] working very hard. Then to picture [illegible] I'd kind of like to just [illegible] typical flight on [illegible] touch on some of the [illegible] pilots life as [illegible] as it regards [illegible] this discussion, [illegible] and some [illegible] say in [illegible] here [illegible] is something [illegible] environment. [illegible] it is not [illegible] safety is [illegible] will [illegible] as a number [illegible] as it is in our discussions here, fuel efficiency has to take kind of a number three slot. In seeking greater fuel efficiency, we just cannot sacrifice safety. I've sat on many a panel and sat in many a workshop where you get talking about efficiency, and it is so easy to get running away and become very efficient and find that you've stretched safety a little thin sometimes.

The numbers are fun to work with. Twenty-two million gallons a month is what we burn. That is about 264 million a year, and at today's price that is $282,500,000. Those numbers are small compared to maybe some large airlines, but that is an awful lot of fuel and an awful lot of money especially when you look back at what it was costing us in some years past. Just to pick it up in 1978 for instance, we were paying a yearly average of 39 cents a gallon. In 1979 that went up to 56 cents, and in 19[illegible] it was [illegible] cents, and that 87 cents is 118 percent over what it was in 1978. January of this year, it [illegible] cents, in February a $1.[illegible], and we were [illegible] around a $1.07 a gallon in and around that area right now. A year ago, it was [illegible] cents a gallon. Just based on what we are paying today, that is $4,840,000 more just to do the same thing this March than we did last March. If you are wondering why your airline tickets are going up, that is where it's all going.

What is being done about it, and who is doing it. Well, I think that everybody here is pretty familiar, but I'll just go through it. The manufacturers are doing their part. They are coming out with new technology airplanes. I'm not going to say through all this whole thing that I will outline everything that everybody is doing, but I think we all need to do a little bit more. Everybody is coming up just a little short. We've made great progress so far, but to really get at this problem I think everybody is going to have to do a little bit more. In [illegible] areas, there is an awful lot to be done.

Manufacturers -- new technology airplanes. We have high-by pass ratio engines, advanced technology wings that have greater span and [illegible] thickenss, less seen and [illegible], and a lot of weight reduction with new materials. [illegible] getting into more sophisticated flight management systems that really assist the crew in flying an airplane at a minimum cost. I think that the manufacturers have come a long way in improving existing models. They've done a great deal with drag reduction, engine improvements with improved exhaust mixers and recontoured fan blades and the like. It's kind of interesting as I looked through a Boeing publication the other day to see some of the improvements that they've made in some of their models as other manufacturers have also in theirs, but I was kind of interested in one figure. The 737-200, today the most advanced model of that airplane, has increased its revenue passenger miles and its lift and [illegible]

capability by 1[illegible] percent from the first model which is pretty significant. They have managed to improve the 737 by 75 percent. A lot of these improvements have been made with weight reductions. All manufacturers have managed to bring the weight down. To use the 727 as an example, they have taken 1,070 pounds out that 200 model since 1976. I think that is fairly significant.

The airlines are trying to do their part. They have done a number of things such as reduced fuel burn. Everybody is into computerized flight plans now. As you all know, that helps us pick the most efficient altitude route for the day. I think we are all working very hard at improving those. Here, as you all know, is where the weather factor comes in. For example, the more accurate the winds and the temperatures, the more accurate the flight plans will be. Many have retrofitted older airplanes with on-board performance computers which most will realize from 1 1/2 to 4 percent improvement in fuel efficiency. Most airlines have gone through drag weight reduction maintenance programs, and almost all have gone to reduced cruise speeds and instituted conservation procedures. Just to give you some more numbers, about a year or year and a half ago, we went to a speed reduction program with our DC-9's. We reduced the cruise speed to [illegible] mach and [illegible] knots. The 1980 average fleet burn on the DC-9, compared to 1978, showed a 6.2 percent reduction in burn which is fairly significant for an airplane of that vintage. That produced on today's burn a 7 1/2 million gallon savings in fuel for a year which is 8 million dollars at today's costs.

The other thing that most airlines are doing is replacing the less fuel efficient airplanes with newer, more efficient models. On our airline, we'll see the BAC-11 parked within a few years and probably the 727-100 as their fuel efficiency figures fall with the rising costs. Another thing that we've done, and we try to keep very close dialogue with our dispatchers on this, is to eliminate unnecessary fuel tankering. I don't know if you've gotten into much discussion on that today. A few years ago, and I don't know to what extent that the price differential exists today in various stations, but what would be normal practice is if we could buy fuel in Pittsburgh at much less than we could buy it in Wilkesbarre, and we were going to Wilkesbarre and back; then, we just put a little extra fuel on in Pittsburgh, so we didn't have to buy that expensive fuel in Wilkesbarre. That kind of a thing would permeate our operation. With the way fuel is going today and what it costs you to lift that kind of weight, we can't afford to do that anymore. We notice it on the longer routes with the heavier airplanes. You try to get a heavier airplane up to its optimum altitude, and it has too much fuel on-board, in fact, more than what it needs. You can't get it there, so you pay a very severe penalty for carrying that fuel around.

We've gone to reduced APU burn, and that program was not without its problems. We really had a hard driving program to get our pilots not to use the APU so much. We almost ended up in a few fights on the ramp with some wanting to shut it down and some wanting to keep it running, but we managed to work our way around that. In all these cases, of course, there are a lot of things to consider. You have passenger comfort to consider and so on.

We've been buying digital color radars for our airplanes and trying to improve the tools that the pilot has to work with. The reception to those has been fantastic. For experienced pilots, who have been operating in weather for years throughout their whole carrers to come in and really rave about a piece of equipment like that and what they can do with it, speaks well for the equipment, I think. The manufacturers have come a long way with that stuff.

The government has done their share. NASA--what do I need to say about NASA? They are into everything. In fact, everytime I come to one of these things and talk to somebody I find out something new that they are into; therefore, I'm not even going to go through that list. The FAA continues to seek improvements in ATC, and some of my remarks a little further down the road are going to hit them just a little bit because I think there is a fair amount of room for improvement there. Some of the things they are doing that are to our benefit right now are the gate holds, so you are not out there burning if you're not going to get off the ground. For many operators, particularly our operations, in places like Pittsburgh and Chicago, that poses another problem. It's fine to say, well great, you don't have to start your engines and go anywhere until you can get off the ground, but how about the four flights that just landed and don't have a gate? Somebody has to go somewhere, and somebody is going to be sitting somewhere whether your engine is running or something like that. The gate hold doesn't always work for us, and it means you do have to start up, go someplace, and shut down.

I think that those of us who fly in today's environment everyday see more clean vectoring. In years past, I can remember when we used to go to Chicago on a monthly basis and meet with the controllers up there, and I was surprised to find how many controllers were not aware of the fact that slower did not necessarily mean less fuel. Today, we find a little better awareness of that, and we're getting more vectoring at speeds that don't require us to put flaps down and don't require all that power. We still have a lot more of that than we really should have. We find we're getting more efficient descents than we used to, but that's still not where it ought to be. The climbs are less restricted, and we're able to get to cruising altitude faster.

Let's kind of pull all these things together and go through this flight profile we talked about and see some of these things in action. The pilot shows up for his flight. He goes in and takes a look at his computerized flight plan and checks his weather. Today, there is much more weather information available to the pilot than

ever. One of the things that we were kind of excited about around our place and looking forward to this summer is the new radar we have, so the dispatcher can really give a pilot real-time information on the severity and the exact location of severe weather. The flight plan enables him to pick an efficient altitude and a route, and he goes through the pre-flight. Airlines are looking at an airplane now, if it is a new airplane, most airlines are going to the no-paint scheme. Depending on what kind of a paint job is on, they may save 100 pounds, maybe 200 pounds, but every little bit counts. In looking at some of the new airplanes, I just think about one we just took delivery of a month ago for a number of significant drag improvements made on that airplane that cleaned it up. These are things that we all have working for us today that we didn't have working for us not too long ago.

We get in, and we go through our check list. We program our performance data computer system, a very handy gadget, not only does it give you power settings that are complex and difficult to take off a chart, but it does so many other things for you. It's going to tell us what an efficient climb speed; it's going to tell us what the efficient cruise speed is; if we can't do to the altitude we want to go to, it's going to tell us what speed we should be operating with at the other altitude. It will help us plan the descent, and of course, it keeps track of a number of other data points that are vital to the flight. We program that, and we prepare to start our engines. The pilot has to determine whether or not he should start his engines on the signal, or do we wait until we start to move? Is the push-back going to be delayed three minutes? It doesn't sound like a big deal, but if you were to start the engines two to three minutes early for every flight you dispatched, you'd burn an awful lot of fuel that you didn't have to burn. We taxi out, and we experience a delay. If we experience too much of a delay, our procedure calls for shutting an engine down. Many airlines taxi out with an engine shut down. There are a lot of considerations for the pilot in that area. You can start two out of three engines and find that you have to use too much thrust just to move out of the area, and it becomes impractical to do that. In any event, we're ready for takeoff and off we go. We're now possibly involved in a noise abatement departure procedure. I guess the most vivid example of that is Boston where we are continually required to fly a number of miles out of our way before we even get on course. Therefore, all of the things that we've tried to save along the way can be actually blown before we really head out in a direction that we want to go in. We get out at 10,000 feet, and we're on our way. We use our programmed climb speed, and we know that's giving us the best fuel efficiency we can get to cruise. There are a lot of things we could use in turbulence information. Usually in today's operation, you are only talking about one or possibly two altitudes that you can operate at. That is all you have because of the separations up there. Hopefully as the future brings advanced technology and altimetry etc., we'll be able to reduce that separation above 29. I did some numbers about a year ago on that, and we were looking at almost a 2 percent fuel savings just by being able to take advantage of that one notch higher altitude in our operation. The pilot again is faced with a number of problems. He has to consider his passenger's comfort. If he goes up to his efficient altitude and it is too rough, does he stay there and save the fuel, or does he go down and give the passengers a smooth ride? Well, obviously that is something you have to wait and decide on when you get there. Is it too uncomfortable?

The speed disciplines are just so much more critical than ever before. This performance data computer systems says you will hold 0.795 mach, and that's what it means. If you do that, you'll get pretty good efficiency. If you hold that schedule all the way through and adhere to it, you'll get the fuel efficiency it claims to give you. The descent planning is so important. So often we can plan the ideal descent, but we're not permitted to do it. As you all know, if you descend too soon, you're involved with level flight at a lower altitude than you should be at. You're burning more fuel than you should. By the same token, if you're required to stay too high, too long and in an idle thrust descent, you have to add drag in order to meet altitude restrictions; then, you haven't accomplished anything there either.

We get into the vectoring environment, and hopefully, we can vector at 210 knots or better. So often we find ourselves at 160 knots with flaps hanging out, the throttles pushed all the way up, and we burn an awful lot of fuel doing that. Excessive vectoring for noise abatement considerations exists at some airports, not too many, but it's costly. The airlines spend an awful lot of money of FAR 36 Noise Standards, and they really should be reaping a little bit more of the benefits in the form of less restrictive vectoring for noise.

We get in closer, and so often we find in many airports that we're required to reduce speed substantially to follow small, slower airplanes. It may be time to think a little more seriously about segregation by speed capability in order that maximum fuel efficiency can be extracted from the machines. A few other refinements such as delay of flaps to the lower altitudes when the weather permits, and taxiing with an engine shut down are things that are reducing noise and saving fuel. The final question is, when the engines are shut down and the parking brakes are set, did we beat the flight plan? We found among our pilots, and I think among most airlines a very active participation in trying to beat the flight plan and to be efficient.

I've touched on some of the considerations that affect fuel efficiency today, and I'd like to conclude about what I think it will take in the future to produce maximum fuel efficiency. The first thing that we need is an efficient machine. The second thing that we need is a maintenance

program that will maintain that machine to preserve its efficiency. The third thing is that we have to have a pilot group that will operate it efficiently. Fourth and the most important, I think, is that the machine must be permitted to operate in an efficienct environment. Now, if this package of efficiency is required to operate in an environment which will not permit that efficiency to be utilized, its value will never be fully realized, and we'll always be using more fuel than we should be.

That concludes my talk, and I'd be happy to answer any questions anyone might have from this group.

Question and Answer Discussion
(questioning parties-unidentified)

Question: In one of our discussions today, the area of the relationship between wind and winds aloft and efficiency arose. Can you tell me as accurately as possible what are the winds aloft for flight planning purposes? Some of these discussions came around to the need for the airlines to cooperate more fully among themselves, to pool winds aloft information from various types of avoidance. Some are avoiding digital voice recording, but we talked about some sort of digital down link. I asked if this aircraft does include your airline. The concept came up that there needs to be cooperation to central pool information that could very well affect efficiency. I'd like to hear your comment about pooling of the sources among the airlines. It's sort of making a kind of big to do, but the pay off could be bucks.

Answer: Well, there's no question that there is a lot of value in that. Whether or not you ever get that kind of cooperation and coordination among all the airlines to do that is a question that I'm not too sure of. I think that each is trying to do it in their own way. We are in my department actively seeking Omega's although we don't have an immediate need for long range navigation. However, in order to give us the capability to accurately measure winds, I don't think that's something that can't be done, and we already reap some of the benefits of that by nature. At the present time, we don't have our own computerized flight plan system. It's in a development stage, and we buy our computerized flight plans from Eastern Airlines. We reap the benefits of their Omega equipped airplanes. We find that our flight plans that come in the areas where they do the most flying are the most accurate. For example, across the north to Minneapolis and places such as that where they are not too active, we find that they are not quite the same. There is definitely a need for that.

Well, there are not too many questions, Jack. They really took the fight out of them today. I took a little shot at everybody. I thought maybe they'd want to take a shot back or something.

Question: Is it difficult to balance capital investments for new aircraft against projected savings because of wind falls or route densities or what ever else?

Answer: I'm not a financial man, but yes. If you just look at it basically, you start to look at what it burns and what it carries. It doesn't take too long to figure out that when the price of fuel hits a certain point and you add up what you'll get out of the fares, even when you fill the airplane up, you're not going to cover your costs. That is what each of these old airplanes approaches. The other thing that happens to you is that as the airplane becomes old, the maintenance burden becomes more expensive. That just increases the total operating costs of that airplane, and it really goes to a fleet basis. For instance, if you look at our DC-9 fleets, some of them are getting pretty old now. What we need is an infusion of new airplanes. For example, we have sixteen new DC-9's that come into the fleet starting in September, and some of the old ones will be retired. That will raise the overall efficiency level of that fleet, and increase its longevity in the light of rising fuel prices.

Question: Is that a two man or three man crew?

Answer: Two man crew. There's a lot of discussion going on about that, and we were pleased to be able to go down and talk to the Presidential Commission last week. I don't think we want to get into any kind of a major discussion about it, but I would like to say though that we feel on our airline that we can speak with some authority about two man versus three man. I feel that I'm in a position to talk about it. I fly a two man airplane and a three man airplane. I think that one of the secrets to it, and an ingredient that shouldn't be over looked is one group may say that a particular airplane or type of airplane should be operated with three, but I think you have to look at what has another group of people done over a period of years. If an airline has never operated or group of pilots has not had a lot of experience operating a two crew airplane, there is a dimension that's missing from their operaton as opposed to that airline who has.

Question: What are you projecting for fuel costs in the next year or two? Are you expecting it to level out somewhat for a year or so?

Answer: Well, I don't know for a year, but they're looking for some leveling in the very foreseeable future. It's starting to show some signs of starting to flatten out a little bit. I guess there's a bit of a glut now, but that will change very rapidly because refiners will probably cut back production and correct that situation very quickly.

Question: Do you use the simulator for proficiency checks and so forth to save any?

Answer: Oh yes. Let me just give you an example of what that saves us. The number came across my desk about a week ago. We were in the process

of upgrading our DC-9 simulator to give it landing approval capability, and it takes a lot of down time on the machine for the engineers to do that. We bought some simulator time from Ozark, and we sent our guys out there to do some training, but we had a lot of proficiency checks that just had to be accomplished now because the guys were running out of time. We grabbed an airplane, and we accomplished fourteen proficiency checks o.k., and we spent $200,000 doing it. Fourteen proficiency checks is nothing; that's just a couple of days work in a simulator; that's peanuts! We have 1,200 pilots, so if you equate that to larger airlines than us, you're looking at an awful lot of money. You just can't afford to train without simulators anymore; it's impossible. Not only that, it's just not a safe way to train anymore. I trained for six years before we got simulators and found that although it's not as much fun to sit in back of one as opposed to sitting in a seat flying an airplane, it is a better tool, and it is a whole lot safer and more efficient.

Question: Within USAir's route structure, what geological phenomena gives you the most problem relative to your operations?

Answer: Where we operate, I would have to say that the ground conditions and icing on the ground, in other words, ramp conditions and runway conditons, are probably the most restrictive. Once you get up and going with these airplanes, you just seem to take them for granted. They're such good machines in that regard. The airports are a mess. You get there, and you just have a mess on your hands. You're on the ground for 30 minutes, and the airplane is covered with stuff, and now you have to deice them. If there are delays getting off the ground, the pilot is constantly in a position of making a decision whether or not too much time has transpired since he had his airplane deiced. We're kind of proud of our car wash in Pittsburgh. I don't know how many of you are familiar with that. Did Jim go through that today? It works very well, and it is very efficient as opposed to doing them on the gate, but that's an awfully expensive proposition when you start deicing airplanes. I would have to say that is probably our major problem.

Question: What kind of material are you using that deices, ethylglycol?

Answer: Yes, and it varies. They mix it. Above 28° they use a hot water mixture with it and vary the amount of hot water depending on the temperature and knock off the stuff with that. Then, if it is not too cold, that will usually hold it. The thin mixture will hold it, but if it is colder than that; then, they get to the stronger mixtures.

Question: Can you recirculate that thing?

Answer: No.

Question: Does it just go down the drain?

Answer: Mother Nature gets it. There have been a few people toying with installations that would recycle that, but as far as I know today, I don't think anybody has really perfected anything like that.

Question: Are you actually removing paint from airplanes, or are you just not painting new ones?

Answer: Well, we have a normal cycle they go through, and ever so often, they go through the paint shop. I'm almost ashamed to tell you this but, when appearance was an important thing to us, an airplane would come in on an overnight thing where they had an overnight check, and they would go through what they call the Roller Derby. They'd put it on the rollers. That is what I was eluding to before when I said that it depends on how the paint was put on. Some of that stuff looked like a battleship, you know! We say that you've got to get rid of some of this paint! Some say that it's clean and smooth, but it's heavy! So, now I think we are all pleased with the new lack of paint on the machine.

Question: There were Congressional hearings last week on the impact of aviation weather on aviation safety, and at these hearings the Air Line Pilots Association made a statement that given the choice between economy and safety, management would come down on the side of economy. What is your comment about that?

Answer: Well, I just don't think that's true. I think that may just come from a real thorough misunderstanding of what motivates management to do certain things. I have to say in all fairness that I think that I'm in a unique position to comment on that. In honest ways, I see both sides. I still fly the line, and it's just not true. Now, I can't speak for all companies, but I think I can speak for our company, and for many other companies that I know very well. Certainly, you strive for economy because you can't just throw that out the window. However, to say that it comes before safety, I just don't agree with that. There are a lot of things that an airline does everyday that are not always discussed with the folks from the ALPA that really go unnoticed and unknown to many. Nevertheless, they are there, and they are in the name of safety.

Question: Why are you flying both sides of the line if you say that being a pilot is also a part of management?

Answer: Why I am I doing that? I don't think I could give up the flying part to be honest with you. The real reason I think that a person in my position has to do both is that I really don't think that you could effectively manage a group of pilots if you didn't continue to fly. I don't think you'd ever have too many opinions that would be respected after awhile. In the beginning you would, but after a long period of time transpired where you hadn't actively flown the line and been involved with the everyday problems, it's really hard to identify with the everyday problems that face a pilot. I couldn't

conceive an affective manager being affective very long unless he knew what that man's problems were everyday.

Thank you very much. I appreciate the opportunity to speak to you.

SECTION V

IMPROMPTU PRESENTATIONS

REVIEW OF FAA STATUS OF RECOMMENDATIONS
DOCUMENTED IN PREVIOUS WORKSHOPS

Joseph F. Sowar

Federal Aviation Administration, NEXRAD

When Walter Frost called me several weeks ago to discuss Frank Van Demark's concern for how the agencies were getting the workshop committee recommendations to the attention of top management and asked me to review what effect the recommendations had on the FAA's programs, I first gave him the old standard response that I just didn't think I had enough time to do justice to such a report. Nevertheless, Walter prevailed. He kept after me so I told him I'd see what I could come up with. By the way, in Frank's report on this, I think he was talking only about last year's proceedings, but Walter put it to me like we ought to review all four of the past workshops. I had copies of all four of the proceedings from the previous workshops, and I took it upon myself to review them all. I thought it would be simple enough to list the recommendations from each workshop and then relate the recommendations to our FAA aviation weather program. That tactic just about blew my mind. Do you have any idea how many recommendations have come out of these head to head committee sessions? When I passed 110, I quit counting, and at the same time I decided that I needed to take another approach. Besides, I was only given ten minutes up here to tell it all, and there was just a whole lot more than that to tell. So, I made a 180 degree turn and took an alternate tact. I decided right off to agree with Frank, at least where the FAA is involved, and admit that we haven't really gotten top management's blessing on the workshop recommendations. Having made that admission, I now must disagree with another item that was in Frank's letter which dealt with the way the workshops were run. I disagree on the point that we have had an over emphasis on bringing together various disciplines, for I feel very strongly that the mixing of the disciplines have been the mother of innovative ideas, the father of meaningful recommendations, and the true strength of purpose embedded in the output of each of the workshops.

These workshops have been an education for all participants. They have straightened out our thinking on many problems that we didn't even know existed. For instance, if we hadn't talked to the simulator experts, how would we have known what kind of wind shear profiles they needed to simulate the various types of wind shears? Such interplay gave needed direction to our wind shear data collection program and was incorporated at the program level. Let me give another example. In the early workshops, there were strong recommendations for a system to measure Slant Visual Range (SVR), and FAA spent many dollars unsuccessfully trying to develop such a system. However, after interfacing with many airline pilots here at the workshops and discussing this issue, we found that they liked the RVR system. They know what to expect to see when they break contact with a reported 3,400 ft RVR. Many felt that the SVR would probably cause confusion. They now (and they were the original ones asking for SVR) give SVR a much lower priority and so do we. In the meantime, we all agree we should make the RVR system as accurate as possible and continue work on measurements down into the very low visibility regime. The point I would make is this. The workshops have been just as important to us in telling us what not to do as they have been in recommending what we should do. Maybe, just as important as those two features is the fact that the workshops in many instances have provided us with reassurances that our programs are on the right track.

Yesterday, Frank Van Demark discussed Meteorology Impact on ATC System Design. He told you about FAA's Aviation Weather Program and Flight Service Station Automation (FSS), about Next Generation Weather Radar (NEXRAD), and Automated Weather Observation Systems (AWOS), about Center Weather Service Units (CWSU), and NADIN high speed communications, about Automatic ATIS and En Route Weather Display Systems (EWEDS), about hazardous weather displayed on air traffic controller displays, about experiments in the Cleveland Center, and FAA's efforts to improve weather information for helicopter pilots flying over the Gulf of Mexico. He told you much more than that, but that is enough to make several points. I venture to say there hasn't been one of these programs that hasn't either been substantiated, modified, or even redirected as a result of what we have learned through the very unique features of these workshops where the forum has permitted and encouraged communications across the interface boundaries between pilots, meteorologists, airplane designers, operations personnel and researchers, as well as between military, civil, general aviation, and commercial interests.

Here at Tullahoma, you tell us about your problems and successes, and we tell you about ours, and we all go home knowing what is going on and what to expect over the horizons. Nevertheless, we still need to formalize action items and do a better job of getting workshop recommendations to the attention of top management. I truly believe that, at least in our FAA program. With this in mind, I hope that each committee chairman makes a strong effort, as Walter has asked, to prioritize the committee recommendations and also to take a real strong first crack at identifying the responsible agencies.

WHAT THE NWS IS DOING AS A RESPONSE TO THE WORKSHOPS

John Blasic

FAA/NWS Representative

I would like to share some background with you on programs that are underway in the NWS in response to user suggestions and recommendations. The first program is the Aviation Route Forecast Program (ARF) which is an interactive system for pilot self briefing. One of the weakest components of current weather service is dissemination. Under development by the FAA and NWS, this program uses an interactive work station for forecast production and integrated so that specific weather information can be directly acquired by the user by means of computer processing.

As meteorology begins to address the task of improving local weather services, new and improved tools will be required to assist the meteorologists in reacting to changes in weather conditions on a smaller scale. Today, meteorologists formulate forecasts either mentally or on paper and then must express them in writing. Composing area forecasts is time-consuming, thereby, reducing the time available for the decision making process. One of the objectives of the ARF program is to provide the meteorologists with the capability to quickly describe meteorological variables by computer graphics. The electronic stylus of the ARF graphic system is a much simpler process allowing selective changes and amending to any variable. The user's data base is automatically updated with every new entry.

In 1973 the DOT recommended that a greater emphasis be placed on mass dissemination of aviation weather data since existing systems, and the one-on-one method of briefing pilots was not satisfying the requirements and was labor intensive and costly. Meanwhile, it was hypothesized that pilots could partially brief themselves by directly accessing a computer base of retrievable weather messages. This lead to the prototype development program known as the Voice Response System (VRS) whereby, a user accesses the computer weather data base by using a Touch Tone telephone. This program was successfully demonstrated for the last couple of years in the Washington, D.C. and Columbus, Ohio areas. Public use of the VRS has been substantial with the favorable user opinion apparent in response to an FAA survey.

Early development efforts in pilot self briefing highlighted the information overload problems presented by narrative types of data when used directly by pilots and are inefficient for planning any given route of flight because of wordiness and fixed areas of coverage. These factors indicated a need for new methods of describing area-type aviation weather phenomena which resulted in the NWS proposing a new grid data base concept, ARF, in 1977. The ARF retrieval is based on a 50 mile corridor on either side of the aircraft course. The VRS output poses the greatest complexity for retrieval since the aural output must be more concise than the visual output of the direct user access terminal (DUAT).

A couple of simulation tests during the twelve week period in 1980 demonstrated that the output route briefing proved to be an adequate representation of the forecast input. Furthermore, most pilots found the data clear and easy to read because its route oriented nature was a very attractive feature because the need to sift through and filter a considerable amount of information was no longer required. Further testing is planned in the fall of 1981 using an enhanced worked station (RAMTEK 9400). Work station configurations along with manpower requirements for continuous updating will be determined and will influence FAA's planned national VRS implementation for the early 1980's.

In the age of information, the forecaster is in danger of being overwhelmed with observational data. Extracting essential weather information from the mass of raw data requires a sophisticated real-time information processing system. This is a joint effort between the FAA and the NWS, and we are moving along very nicely in that area.

The next program I'd like to call your attention to is the Aircraft Meteorological Data Relay (AMDAR). AMDAR represents the kind of innovative system necessary for the decade of the 80's to increase the efficiency with which our limited energy resources are used. AMDAR can provide the frequent, accurate, and timely wind and temperature reports needed to update forecasts of these parameters at several centers around the world. This system will consist of a relatively small avionics unit on board a current wide body and next generation aircraft that takes wind and temperature observations every seven and half minutes. Once an hour after eight samples are taken, a report is sent via satellite stations or entered into the Aeronautical Radio Incorporated Communications System (ARINC) via VHF transmission. More frequent sampling and transmission is possible when the aircraft are over or near the United States. When AMDAR equipped aircraft are ascending from or descending to airports, they can be commanded to go to a rapid sampling rate and thereby, provide a vertical profile of the atmosphere along the flight path. With numerous aircraft providing this data, the density of data could be increased sufficiently to enable true mesoscale forecasting. The aviation community also directly benefits by receiving wind shear data above airports, and the airline industry benefits by having a flight following capability for their aircraft over oceanic areas.

Among other improvements, there could be more frequent wind forecasts, earlier transmission of forecasts, and more frequent amendments. The primary component of a just completed contract with ARINC was a user benefits study and a strawman specification for the AMDAR avionics unit. The benefit study showed a 45 percent to 80 percent return in investment with a payback period

of one to two and a half years.

Under auspices, the World Weather Watch of the World Meteorological Organization (WMO), a consortium of interested countries, is being put together to fund development work on an AMDAR unit. Ad hoc AMDAR working group has been formed to coordinate international development and deployment of the system. In the United States, an AMDAR working group with members from NOAA, FAA, U.S. Air Force, NASA, and DOE have recently completed a PDP for the entire system. This AMDAR derived data could benefit many users, but the primary beneficiary would be the aviation industry because through improved and more frequent wind and temperature forecasts, considerable amounts of expensive fuel would be saved.

The next area that the NWS is cooperating with the FAA is the Gulf Observation Forecasting and Dissemination Program. An observational program for supporting the helicopter operators and the drillers out in the Gulf of Mexico has been agreed upon in meetings over the last several months. An observational program whereby the operators on the oil platforms and the helicopter operators cooperate has been developed. The forecast program will be dependent upon what happens with the proposed program reductions within the NWS.

An automated observation station, ALWOS, will be placed on Vermillion 245 platform this April for testing and evaluation. The total surface observation program to support both aviation and marine forecasts in the Gulf of Mexico will consist of 53 observation sites including 15 offshore sites, 20 on-shore sites, 17 automated sites, those without ceiling and visibility and without present weather, and one ALWOS. A plan to systematically collect PIREPs was suggested. These pilot reports would be collected by the Houston and New Orleans FSSs and bulletins transmitted at H+15 and H+45. A gulf forecast to serve both aviation and marine operations will be issued twice per day with amendments as required. It will be a twelve hour forecast and a twelve hour outlook. The forecast office in New Orleans will not be able to issue separate AIRMETS and SIGMETS for the gulf forecasts but will amend portions of the forecast as required. The proposed forecast program startup is July 1981, but proposed programs in NOAA and the NWS could impact this startup date.

The next subject effort is the Center Weather Service Unit Direction. The Center Weather Service Unit (CWSU) Program began in 1979 using NWS meteorologists located in the route traffic control centers to provide meteorological consultation and advisories to air traffic personnel. Being dedicated to the aviation weather, these meteorologists significantly enhance air traffic safety and operations. Several aspects of the CWSU program particularly in light of the envisioned future aviation weather programs should be noted. First, the CWSU meteorologist does not have direct communication with the pilot as does the flight watch specialist. The relay of weather information to the cockpit is through air traffic personnel. Secondly, the funding to support the CWSU is provided by the FAA, and operational supervision is under the direction of the center chief. The NWS provides the administrative supervision. As the CWSU program evolves, more NWS aviation program responsibilities may be shifted to these units. Note the emphasis on may be. This is under study at this time in view of the program reductions that the NWS is proposed to take. The arrangement of having the meteorologists in the air traffic control center has several advantages. First, the meteorologist is physically close to the aviation users, thereby gaining a better appreciation of their requirements and is exclusively dedicated to serving the aviation community. The CWSU has real-time access to weather intelligence solicited from pilots and has access to center communications for rapid dissemination of information. It should be noted that there is an effort underway to improve the communications for the CWSU meteorologists. Leased Service A, the 2400 wpm system that the flight service stations currently have, will be placed in the hands of the CWSU within the next several months. This should enhance their operation until they get into the mid 80's. An enhanced flight service station's data processing system, whereby, graphics and alphnumerics both will be available in very quick time and for on-site processing and storage.

Additionally, some of the products used for Center personnel bear a close resemblance to forecast initiated by our forecast office meteorologists. For example, the Center Weather Advisory (CWA) issued to supplement or update the SIGMET or AIRMET is very similar to these forecast office products. Consideration needs to be given to broader dissemination of the CWAs and perhaps through the issuance of AIRMETS and SIGMETS from the Center Weather Service Units.

The next subject area is the future of the pilot report program. The current system of collecting, disseminating, and processing PIREPs is ineffective, slow, and not systematic, therefore, leaving considerable room for improvement. It is recognized that PIREPs are data gap fillers, verifiers for aviation weather products, and invaluable to all aviation associated users and providers of information to the system. Therefore, it is obvious that the greater the number of usable and more timely PIREPs available, the better the aviation weather information system will function. Until recently, there has been no deliberate effort to solicite PIREPs on a regular basis.

There are two major problems with PIREPs. One is that the data must be arranged in a specific format, and the other is the randomness of the reports. As to the first problem, though a fixed format for PIREP data is theoretically in place with the standard form that is used today, eight to ten percent of an average 1,200 reports per day never get into the system because of encoding errors. Of the reports that do get disseminated, several random samples have revealed errors in 38 to 91 percent of the reports. Most of the

errors would preclude electronic data processing handling.

The randomness p· ›lem will have to be dealt with if PIREPs are to bu used at the National Meteorological Center as input to the first guess analysis. The objective of systematizing the PIREP data is to provide an observational foundation for improved forecast, quality control, briefings, and in effect, safer and more efficient flight operations. Among others, several improvements envisioned are PIREP bulletins segmented by phenonema as wel˙ as location or altitude, automated monitor, alert and verification of in-flight advisories, and real-time amendment of forecast winds aloft.

The next area of effort within the NWS and FAA is really under the subcommittee for Aviation Services within the Office of the Federal Coordinator. The subject is improving icing forecasts for aviation. While the total numbers of icing related accidents appear comparitively small (178 of 17,372 general aviation accidents, 1976-1979) evidence exists that the percentage of icing related accidents is on the increase. Also, the doubling of helicopters in the mix of general aviation aircraft types the numbers of icing related accidents could increase significantly because helicopters are especially vulnerable to icing encounters.

Consequently, the subcommittee on Aviation Services with representatives from NASA, FAA, NWS, NTSB, and DOD has undertaken the effort to improve icing forecasts. In addition, the FAA in cooperation with NASA and DOD is in the process of examining its FAR Part 25, Appendix C, as those criteria apply to the certification of rotary wing and other general aviation aircraft to "fly in known icing conditions".

Literature references state that key elements needed to produce accurate icing forecasts are:

1. Cloud LWC
2. Cloud drop size distribution
3. Cloud droplet temperature
4. Ambient temperature

Of these four elements, only temperature is routinely measured and reported. Therefore, it is reasonably safe to say that the data base for icing forecasts is seriously deficient.

The icing forecast data base consists almost exclusively of surface and radiosonde observations and PIREPs. The courseness of the radiosonde network coupled with the relative infrequency of data measurements does not lend to accurate and well defined assessments of icing potential. If PIREPs are to serve as the primary filler for data between sounding stations and at off sounding times, then other problems arise. First, the distribution of PIREPs is random in space and time. Secondly, general aviation pilots avoid significant icing airspace, and air carrier planes are equipped to handle icing problems.

While dissemination of icing forecasts are critically important to the success of the forecast process, it is inadequate for most icing events.

A number of new technologies that have evolved over the past decade may have relevance to the icing forecast problem. Initial studies on aircraft icing in the early 1950's by NASA formed the basis for much of what we know about aircraft icing. As with icing accretion meters, LWC and DSD measuring equipment have evolved over the years. However, results of testing on ice accretion meters indicate that more development is required on many of them to meet standards for research purposes, and little is said of them as practical warning devices for significant icing encounters. Although LWC probes as well as hydrometer samples are in widespread use, nearly all the data collection is from aircraft and requires large amounts of data processing to determine LWC and DSD.

R&D relevant to improved icing forecasts is almost nonexistant. DOD, NASA, and FAA all have action R&D programs related to icing, but only DOD is trying to improve their icing forecast techniques.

At the last meeting of the Subcommittee on Aviation Services, Frank Coons of FAA submitted a position paper on icing for consideration and action. Input for this paper was provided by the NWS and the other members.

The recommendations contained in this position paper are:

1. The committee decided that further improvements in the forecast of icing are warranted and that potential solutions exist that are worthy of further investigation.
2. That DOD be responsible for the lead in developing the procedures to improve icing forecasts exclusive of communicating the forecasts to users.
3. That NWS be responsible for investigating the potential that satellite data and microwave radar has for improving the icing forecast data base.
4. That NASA be responsible for determining the feasibility of developing ice accretion meters for air carrier and general aviation aircraft including rotary wing. Also that NASA investigate the potential for developing a low cost LWC meter which can be flown on existing radiosonde balloons or made a part of the radiosonde sensor elements.
5. That FAA be responsible for reviewing and changing where appropriate, the existing definitions of icing intensity as they apply to air carrier, air taxi, and general aviation aicraft.
6. That NTSB be responsible for and in cooperation with NWS, DOD, and FAA developing a quality control program

that monitors the accuracy, coverage, utility, and impact of icing forecasts on the aviation community.

The NWS member of the subcommittee on Aviation Services submitted several recommendations to the committee relative to this investigation of the current status of forecasting icing.

1. Develop in collaboration with the FAA and aviation user groups, a systematic routine PIREP collection system. The primary aim of this system should be an active and selective sampling of area regional weather conditions rather than a passive "wait for" system wherein PIREPs filter back to forecasters and flight watch specialists. Also PIREPs should be processed in real-time according to weather type and low or high altitude.
2. Define the role/status, i.e., advisory/forecast of CWSU meteorologists and products, i.e., CWAs/MISs vis-a-vis Area Forecast Center (WSFO) products. Decide if dissemination of CWSU products will be confined to FAA facilities or made available to external users. Currently, the CWSU products are just used internally within the FAA and not made available externally.
3. Initiate R&D efforts within the NOAA/NWS to improve forecasts of not only icing but also of CAT and LLWS. Specialized automated product guidance/forecasts should be developed if feasible to respond to persistent users requirements for improved and timely weather services.
4. Examine further the role of satellite imagery/sounding techniques in determining areas of potential icing.

Question and Answer Discussion

John McCarthy, NCAR: How soon will AMDAR be operational? I tell you why I'm asking is because in the discussion in the fuel efficiency area, the airlines could use that immediately. I'm just wondering how soon. Is it going to be one of those national determinations that results in a long delay? Or is it something that's going to be done rather quickly?

John Blasic, NWS: I cannot answer that quite accurately. I'm not that closely associated with the program. Rick Decker back at the NWS Headquarters is on this working group, and from my perspective I would think it would probably be a couple of years before they develop the unit and place it on-board aircraft.

John McCarthy: Do you know whether the system will provide a separate data base and give real-time winds aloft based on observation, or will it be used to update just the LFM twelve hour model? That is the NMC model to predict winds aloft is based on twelve hour radiosonde data. Do you know if the data from INS winds aloft will be used to create a real-time data base for corrections or will actually go in and correct the twelve hour model?

John Blasic: That's my understanding, that it will be used both ways, but whether they'll have adequate data processing capabilities to update the winds in real-time, I cannot answer that with any certainty.

NASA RESEARCH PROGRAMS RESPONDING TO WORKSHOP RECOMMENDATIONS

A. Richard Tobiason

NASA Headquarters

I plan to summarize what NASA is doing and intends to do relative to recommendations given in the five committee reports from last year's workshop proceedings. Recommendations from the Wind Shear and the Icing Committees are being considered in two ongoing programs: JAWS and Lewis' Icing Program. John McCarthy in his Impromptu address on JAWS will cover what is being done for the recommendation. Comparison of last years Wind Shear Committee's report with the JAWS plan show almost direct comparison of ojects. Peggy Evanich will also give a paper in the Impromptu session on the NASA/Lewis' Icing Program. Her presentation will address the recommendations that were in last year's proceedings. Therefore, I will only talk on the remaining three committee topics, Atmospheric Electricity and Lightning; Fog, Visibility, and Ceiling; and Turbulence.

There were several recommendations by last years Atmospheric Electricity and Lightning Committee. The first we'll consider is related to forecasting lightning and dissemination of information on the probability of occurrence. NASA is establishing a data source with the F-106 flight program at Norman, Oklahoma. One of the objectives is to improve the detectability of lightning and severe storms and help develop operational avoidance procedures. Another recommendation was to study the use of satellite and Doppler radar to detect thunderstorms and forecast the probability of lightning. Marshall Space Flight Center has a program in that area and is working closely with the people at Langley in the F-106 program. This program has been underway for about a year. NASA anticipates that either NSSL, NWS, or FAA will address the recommendation to review existing dissemination systems with regard to data collected from all sources so as to increase speed and quantity of lightning data disseminated to users.

There are three recommendations related to research. The first one is to establish a National Flying Lightning Laboratory. NASA does not intend to implement such a laboratory beyond their current F-106 program. The next recommendation considers strike models. Another objective of the flight program is to gather strike data while Norm Crabill, Hugh Christian, and Bill Vaughan are developing theoretical strike models. The last recommendation relative to research is to find the best way to apply electrical field data to operations. This is an element of both the LaRC and MSFC programs.

NASA does not have a responsibility relative to the two recommendations on improving the current data base and recording these data in the Records Center in Asheville, North Carolina. The two recommendations on ground-based and on-board instrumentation are being accomplished at MSFC and WFC. The objective of these programs is to measure electrical fields for the purpose of lightning probability prediction and avoidance.

One of the major objectives of the Langley F-106 Program deals with the recommendation to design positive hardening techniques to protect modern flight control and avionic systems.

The next major category is Fog, Visibility, and Ceilings. There are a couple of comments that NASA can respond to in the fog area. Wallops Flight Center has a program to relate prevailing visibility to wavelength contrast ratios and the visible spectrum. They are also looking at low cost instrumentation for use at unattended air fields. This is the only work that NASA is pursuing in the prevailing visibility.

In the fog dispersal area, there was a recommendation to continue the systematic R&D program to determine the feasibility of the charged particle concept. This work is continuing by MSFC and is being built by FWG Associates, Inc.

The Turbulence Committee presented several recommendations. There was a recommendation to share more information and get some cooperation between the entire community in the respect of clear air turbulence forecasting. NASA has no direct responsibility in this area.

It was recommended that the 180 gHz microwave passive water vapor radiometer work be continued. Participation here is primarily Bruce Gary's work at JPL and Dick Kurkowski and Pete Kuhn's work at the Ames Research Center. Jack Ehernberger's work at NASA/Dryden Flight Research Center on clear air turbulences numerical modeling and gravity waves is continuing as recommended.

The recommendation to continue John Keller's work on a DRT, Diagnostic Richardson Number Tendency Analysis is being considered.

Again I encourage you to to attend the Impromptu presentations by John McCarthy and Peggy Evanich to learn of NASA efforts relative to the icing and wind shear workshop recommendations. I hope from this quick overview that you will see the workshop recommendations are seriously considered by NASA and play an important role in guiding their research and development effort relative to aviation safety and efficiency.

PROGRESS ON LOW ALTITUDE CLOUD ICING RESEARCH

Richard K. Jeck

NRL/Washington, DC and U.S. Naval Academy, Annapolis, MD

Renewed studies of the icing environment at altitudes below 10,000 feet have been recommended by past sessions of this workshop (Frost, et al. 1979 and Frost and Camp, 1979) as well as other workshops involving the interests of the helicopter industry (NASA CP-2086, 1979 and HAA, FAA Helicopter Workshop, 1979). In response to this need the FAA has initiated a research project with the Atmospheric Physics Branch of the Naval Research Laboratory (NRL) in Washington, DC to carry out such a study. In Table 1 the questions to be answered and the outline of the research plan are summarized.

TABLE 1

SUMMARY OF FAA SPONSORED RESEARCH PROJECT AT NRL

PROBLEM:

INCREASED USE OF HELICOPTERS

NEED TO EQUIP AND CERTIFY FOR IFR AND DE-ICING

- EXISTING AIRCRAFT CERTIFICATION CRITERIA APPLICABLE?
- TOO STRINGENT ON ICING FOR HELOS?
- BASED ON ACCURATE DATA?
- APPROPRIATE FOR LOW (10,000 FT) ALTITUDES?

PLAN:

- REVIEW HISTORICAL ICING DATA
- OBTAIN NEW MEASUREMENTS
- COLLECT MODERN ICING DATA FROM OTHER GROUPS
- RECOMMEND LWC, OAT, AND MVD CRITERIA FOR HELICOPTERS

(IMPROVE FORECASTS OF ICING, LWC, OAT)

In Figures 1 and 2 are shown the icing envelopes as published in FAR-25, Appendix C. They currently apply to the certification of helicopters as well as to transport category aircraft. Since these envelopes are applicable to flight levels up to 22,000 feet, there is a concern that the large values of liquid water content (LWC), especially for the intermittent maximum case (Figure 2), are excessive and unrealistic for helicopters whose service ceilings are generally below 10,000 feet.

Data obtained by the National Advisory Committee on Aeronautics (NACA) during the time period from 1946-1950 form the basis of these FAR-25 envelopes. Our review of these data and the estimated accuracies and known sources of error as described in the original NACA publications have been included in an interim report on the NRL study (Jeck, 1980). In Table 2 the findings of this review are summarized. The main conclusion regarding the accuracy of the NACA LWC data is that the net effect of the possible sources of error of both signs is uncertain. In 1952 after the NACA researchers became aware of the seriousness of runoff errors for measurements at temperatures just below 0°C, they re-examined their data and concluded that not more than about five percent of the measurements they had already re-

TABLE 2

SUMMARY OF NRL REVIEW OF HISTORICAL CLOUD DATA IN ICING CONDITIONS

METHODS OF MEASUREMENT

- Rotating multicylinders (LWC and MVD)
- Coated, fixed diameter cylinder (max drop diameter)
- Rotating disk ice meters (Icing rate)

POSSIBLE ERRORS IN MULTICYLINDER MEASUREMENTS

Principal Source of Error	Max Error in LWC
Runoff (for OAT >-5°C)	Up to -100 or more
Voids or cloudless spaces during multicylinder exposure	Up to -100 or more
Departures from theor. dropsize distrib. and collection efficiencies	?
Airspeed uncertainties at probe	+12
Separating and weighing iced cylinders	± 4

ERRORS IN COATED CYLINDER MEASUREMENTS

Max indicated droplet diameter often = < MVD from multicylinders

CONCLUSIONS

1. Net error in LWC measurements uncertain.
2. Droplet diameter inferences unreliable.
3. LWC measurements may be reliable for "small" drops, large positive errors possible for clouds with large drops.

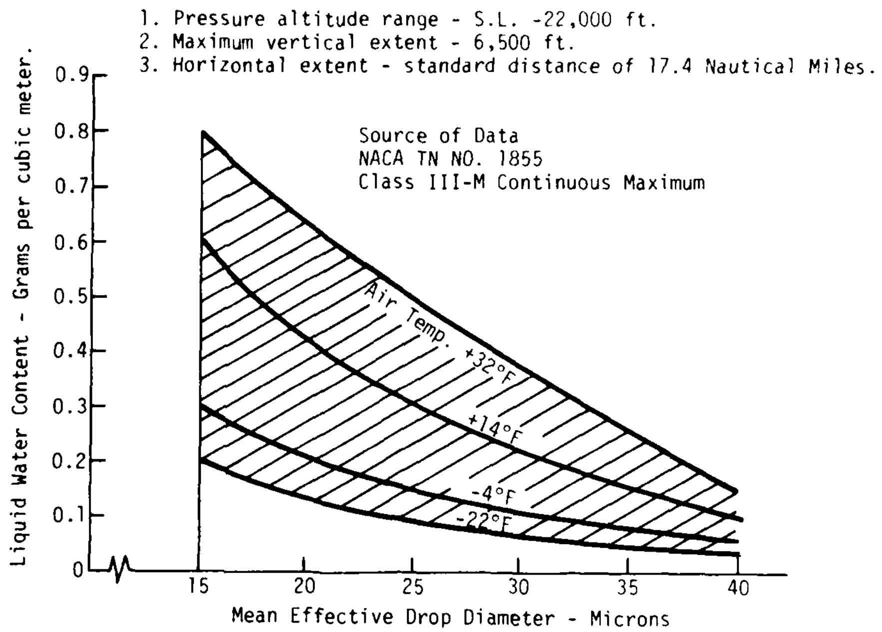

Figure 1. Continuous maximum (Stratiform Clouds) atmospheric icing conditions. Liquid water convent vs. mean effective drop diameter.

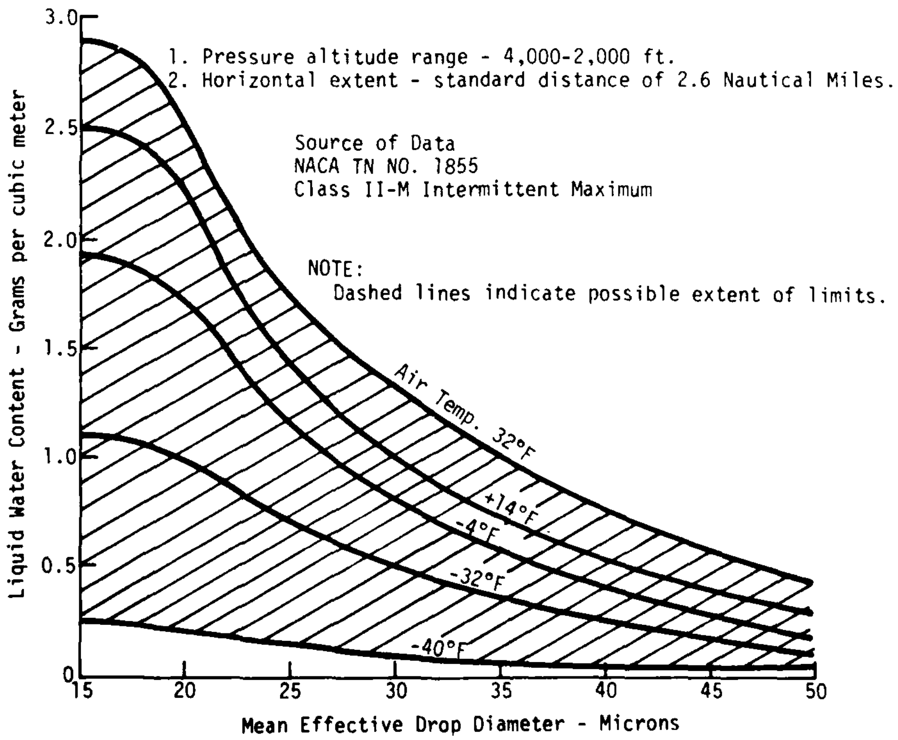

Figure 2. Intermittent maximum (Cumuliform Clouds) atmospheric icing conditions. Liquid water content vs. mean effective drop diameter.

ported would be affected (Lewis and Bergun, 1952). The underindication of average LWC from measurements where the multicylinder probe was exposed in clouds containing recording "cloud indicator" to document the actual duration of clouds and voids during exposures of the multicylinder probes. The result was that significantly larger values of average LWC were obtained when the more accurately determined cloud exposure intervals were used (Lewis and Hoecker, 1949).

Because of frequent contradictions in droplet sizes inferred from the multicylinder probes versus the coated, fixed diameter cylinder probes, the NACA researchers had concluded by 1949 that the indicated droplet size distributions were totally unreliable (Lewis and Hoecker, 1949). However, mean volume diameters (MVD) inferred from the multicylinder method alone were still regarded as accurate for "small" droplets but because increasingly inaccurate as the drop size increases (Lewis and Bergun, 1952).

Table 3 summarizes the status of modern cloud icing data. Present day drop size measurements are generally made with laser probes manufactured by Particle Measuring Systems (PMS), Inc. of Boulder, Colorado. LWC data commonly come from hot wire probes, icing rate meters, and by calculation from the drop size distributions obtained with the PMS probes. The principal source of error known to apply to PMS probes is the ±10 percent uncertainty in particle size determination as specified by the manufacturer. Since LWC is proportional to the cube of droplet diameter, a ±10 percent error in droplet diameter results in a possible ±30 percent error in LWC computed from the droplet size distribution.

TABLE 3

STATUS OF MODERN MEASUREMENTS IN ICING CONDITIONS BELOW 15,000 FT. PRESSURE ALTITUDE

METHODS OF MEASUREMENTS:

- PMS Cloud droplet size spectrometers (N vs. D, LWC, MVD)
- Ice rate meters (Rosemount, Leigh) (Icing rate, LWC)
- Hot wire LWC meters (J-W, King) (LWC)

POSSIBLE ERRORS IN DROPLET SPECTROMETER MEASUREMENTS:

Principal Source of Error	Max. % Error in LWC
±10% in droplet diameter	±30%

SOURCES OF MODERN DATA:

Naval Research Laboratory	(1979-81)
Meteorological Research Inc.	(1979-81)
University of Wyoming	(1980-81)
Univ. of Clermont-Ferrant (France)	(1978-79)

In Figure 3 and 4 are shown a comparison of the historical and modern icing data that have been analyzed to data on the NRL project. The historical and modern data each represent some 400 miles of actual measurements in supercooled layer clouds below 15,000 feet pressure altitude. The historical data are mostly from altitudes between 2,000 feet and 10,000 feet and the modern data are mostly from 5,000 feet to 10,000 feet.

The bar graphs of Figure 3 reveal noticeably different frequencies of occurrence for LWC, with the modern data peaked sharply below 0.2 gm/m^3 compared to a broader distribution for the historical data. The average value of modern LWC measurements compiled here is only 0.13 gm/m^3. This is half the average value of the analyzed, historical LWC measurements.

In contrast, Figure 4 shows the interesting result that the historical and modern MVD frequency distributions are quite similar as are the average values of MVD.

On the assumption that there are no significant errors or unrecognized biases in either the historical or modern measurements, a possible explanation for the observed differences in LWC frequencies is as follows. The majority of historical measurements analyzed so far are from layer clouds associated with frontal or cyclonic

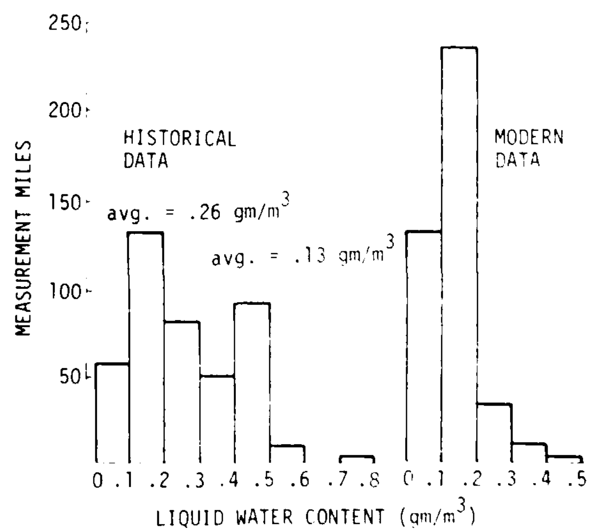

Figure 3. Frequency distribution of LWC from 400 miles of historical measurements (1946-1948 NACA data) and from 400 miles of modern measurements (1978-1979) analyzed to date from supercooled layer clouds below 15,000 ft. pressure altitude.

systems where convection and low level convergence may increase the amount of condensation in the clouds. The importance of such effects was emphasized during a recent NRL research flight over the Gulf Stream offshore from the Virginia-Carolina Capes. There, broken Statu Cu layers about 4,000 feet thick were forming in cold air advecting across the Gulf Stream in a manner similar to that depicted in Figure 5. The data from this flight are not yet completely analyzed. but indications are that the LWC may have been nearly 1 gm/m^3 in the upper levels of the cloud layer! Such LWC values are much larger than for the modern data included in Figure 3. The implication is that the modern data in Figure 3 are not yet representative of a sufficiently wide range of synoptic or mesoscale cloud systems. Data will have to be collected from more weather such as those illustrated in Figures 5, 6, and 7, for example.

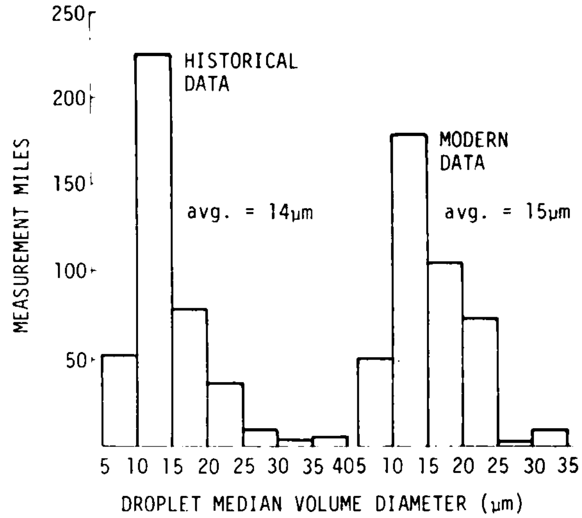

Figure 4. Frequency distribution of MVD from 400 miles of historical measurements (1946-1948 NACA data) and from 400 miles of modern measurements (1978-1979) in supercooled layer clouds below 15,000 ft. pressure altitude.

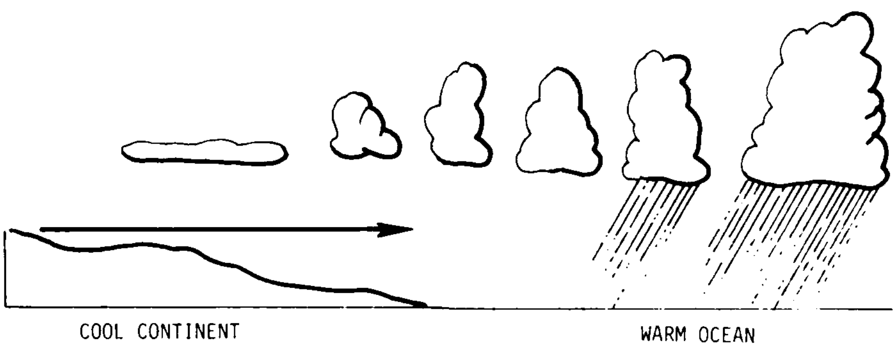

Figure 5. When cP air of winter moves from cool continent to warm ocean.

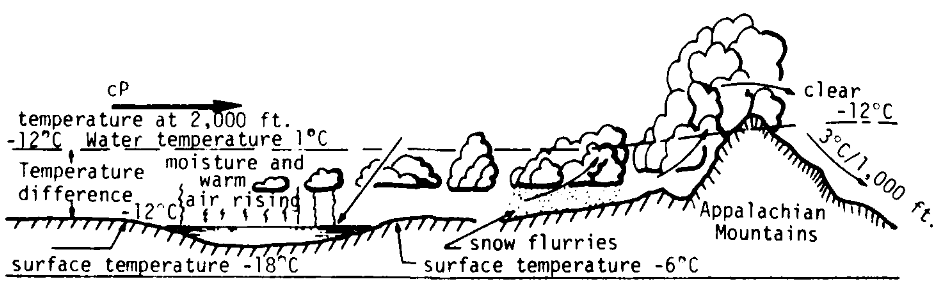

Figure 6. cP air moving over the Great Lakes.

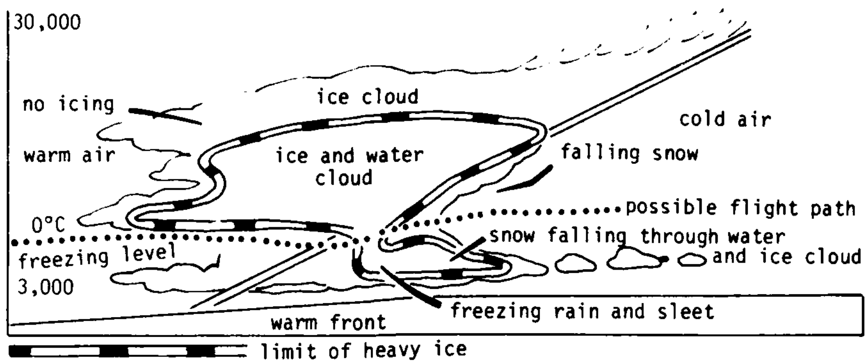

Figure 7. Warm front icing condition.

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NASA/LEWIS RESEARCH CENTER ICING RESEARCH PROGRAM

Peggy L. Evanich

NASA/Lewis Research Center

When NASA/Lewis Research Center re-established an aircraft icing research program in 1979, the first task was to conduct a series of icing requirements studies for commercial aircraft, light transport and general aviation aircraft, and rotorcraft. Each study was conducted by a member of the aircraft industry with the objectives of establishing the state-of-the-art in aircraft icing, determining the aircraft industry's icing research and technology needs, and recommending both short and long term icing programs to NASA. To date, all three studies have shown that all three categories of aircraft need improved and new ice protection system, icing calculational techniques, icing performance sensitivity on current and modern airfoils, and new and improved icing facilities. The rotorcraft and general aviation studies have also shown a need for improved forecasting of icing conditions, a need for updating FAR Part 25, and a need to quantify the icing intensity definitions. The need for a general aviation pilot training film concerning flight into icing conditions was also identified. At this time, the general aviation and light transport study has been published and distributed. The commercial aircraft and rotorcraft contractor reports are in the final review process.

The icing analysis efforts at NASA/Lewis is under the guidance of Dr. R. Joseph Shaw (Figure 1). A number of grants and contracts with universities and industry have been established by him to develop various computer codes of the heat transfer and aerodynamic characteristics that define the icing problem. All these codes will be used in conjunction with the existing in-house potential and viscous flowfield prediction codes at Lewis. FWG Associates in Tullahoma, Tennessee is developing a two-dimensional water droplet trajectory code for flow around airfoils and through inlets while Atmospheric Sciences is developing a three-dimensional code. Airfoil ice accretion prediction codes are being generated by the University of Dayton and the University of Connecticut. The latter work involves identifying the microscopic details of water droplet impaction on surfaces.

An effort is also underway to measure the external convective heat transfer coefficient distribution about airfoils that are accreting ice. This work is being done at the University of Tennessee and in-house at NASA/Lewis. A two-dimensional transient conduction heat transfer code for deicing systems is being developed by the University of Toledo which is an extension of the one-dimensional code also developed there. Lastly, computer codes to predict the aerodynamic performance of airfoils, propellers, and rotors with accreted ice are being developed under grant with the Ohio State University.

Figure 2 shows experimental and analytical results (done by FWG Associates) of the local droplet impingement efficiency for an NACA 65

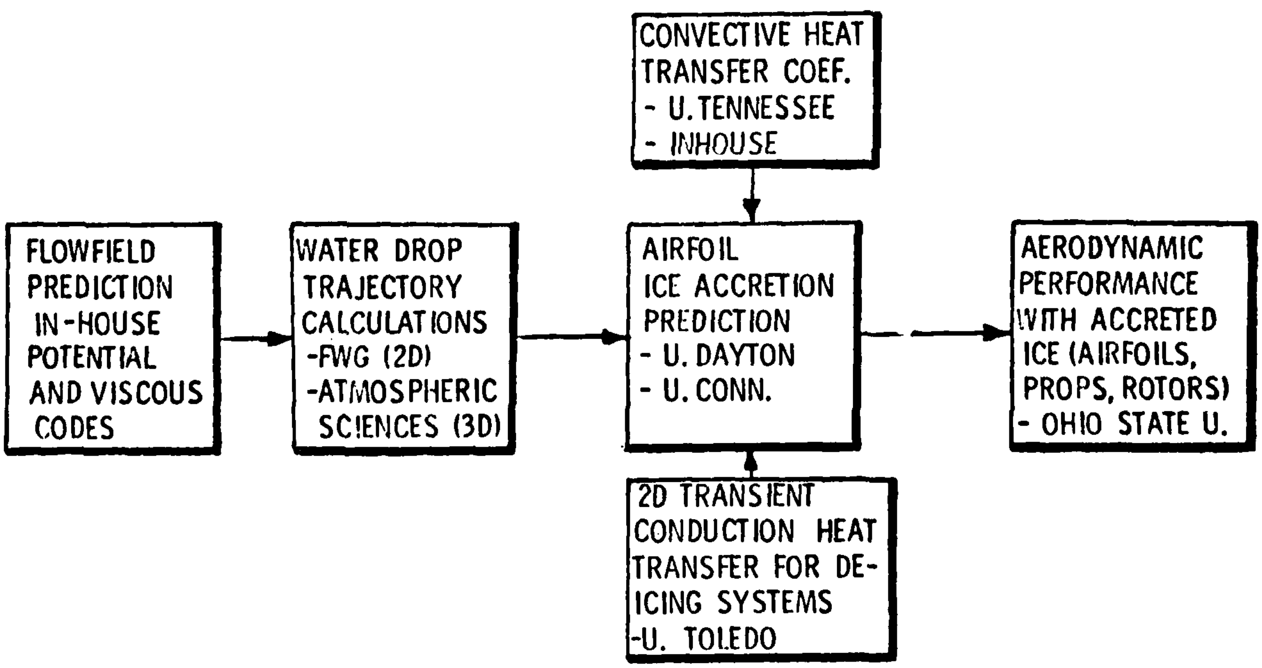

Figure 1. NASA/Lewis Icing Analysis Code.

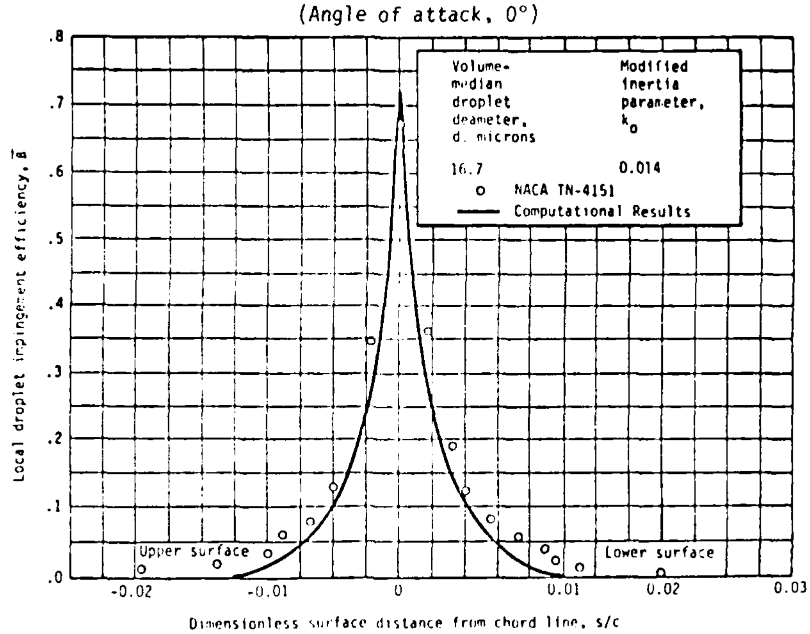

Figure 2. Chordwise variation of local droplet impingement efficiency for 6-foot-chord NACA 65A004 airfoil section.

series airfoil at zero angle of attack. Both sets of results agree quite well. Figure 3 shows similar data for the same airfoil at an angle of attack of 8° with again both results in good agreement.

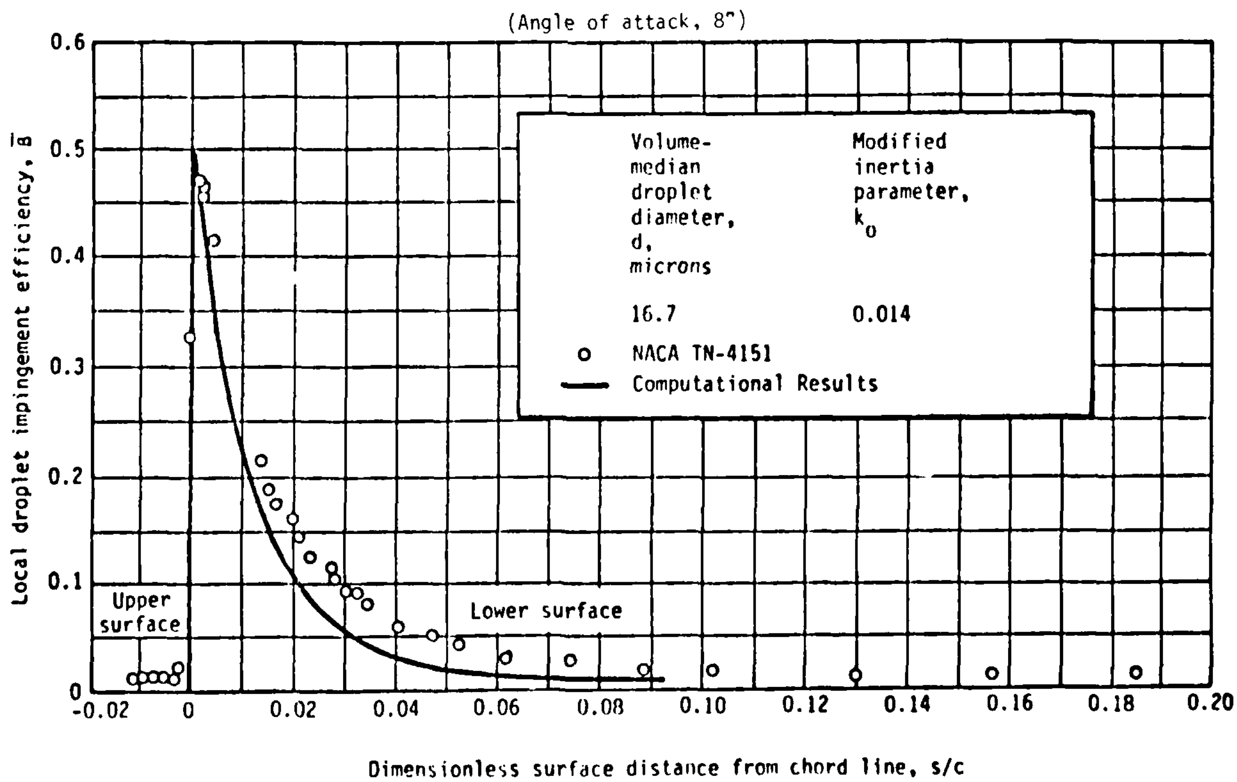

Figure 3. Chordwise variation of local droplet impingement efficiency for 6-foot-chord NACA 65A004 airfoil section.

The three-dimensional water droplet trajectory program being developed by Atmospheric Sciences is capable of handling trajectories around lifting bodies as shown in Figure 4. This analysis will be extended to include both snowflake and ice crystal trajectories.

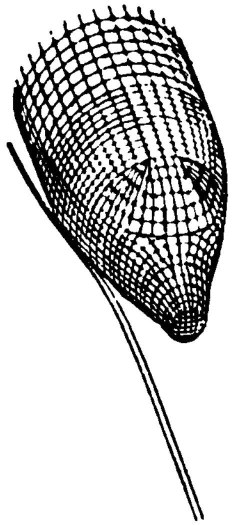

Figure 4. Flux tube of 150 μm diameter water drops to a point near the foward fuselage of a C130E airplane.

Figure 5 depicts the results of the University of Dayton's ice accretion prediction code which uses a periodic updating of the aerodynamic flowfield and the resultant change in droplet collection efficiency. Also shown in Figure 5 is the experimentally observed ice accretion around a cylinder and the Lozowski steady state solution. Although not identical with the experimental results, it is seen that the quasi-steady state solution approaches the observed ice accretion much more closely than the steady state solution.

Temperature-time curves for a point heater thermal deicing system with the ice-to-water-phase change included in the analysis is shown in Figure 6. This work, done by the University of Toledo, depicts the temperature of the various layers in a thermal deicing system with time in a one-dimensional solution. This model is currently being extended to the two-dimensional case.

Results of the aerodynamic performance model of airfoils with accreted rime ice are shown in Figures 7 and 8. Figure 7 shows the leading edge of a modified NACA 64-215 airfoil with results obtained experimentally, from a time-stepped analysis, and from an analysis with no time-stepping used. Although none of the theoretical results agree completely with the observed results, it can be seen that the time-stepping results obtained with the Ohio State University code are approaching the actual geometry of the rime ice accretion. More refinement of the code should result in closer results. Another test case using the Ohio State code is

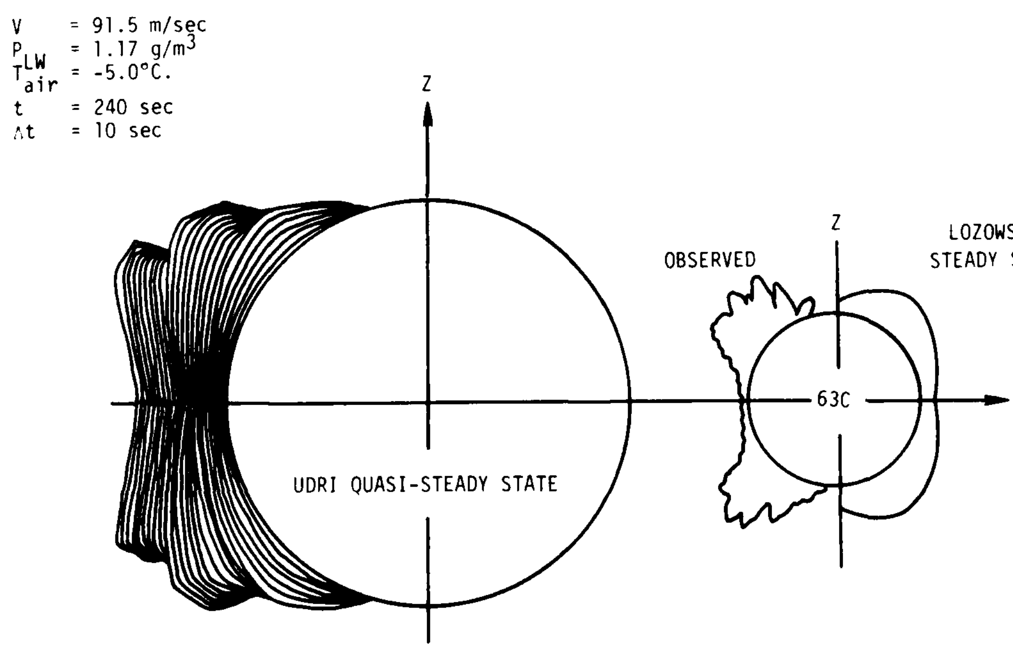

Figure 5. Test 63C (Lozowski, et al., 1979).

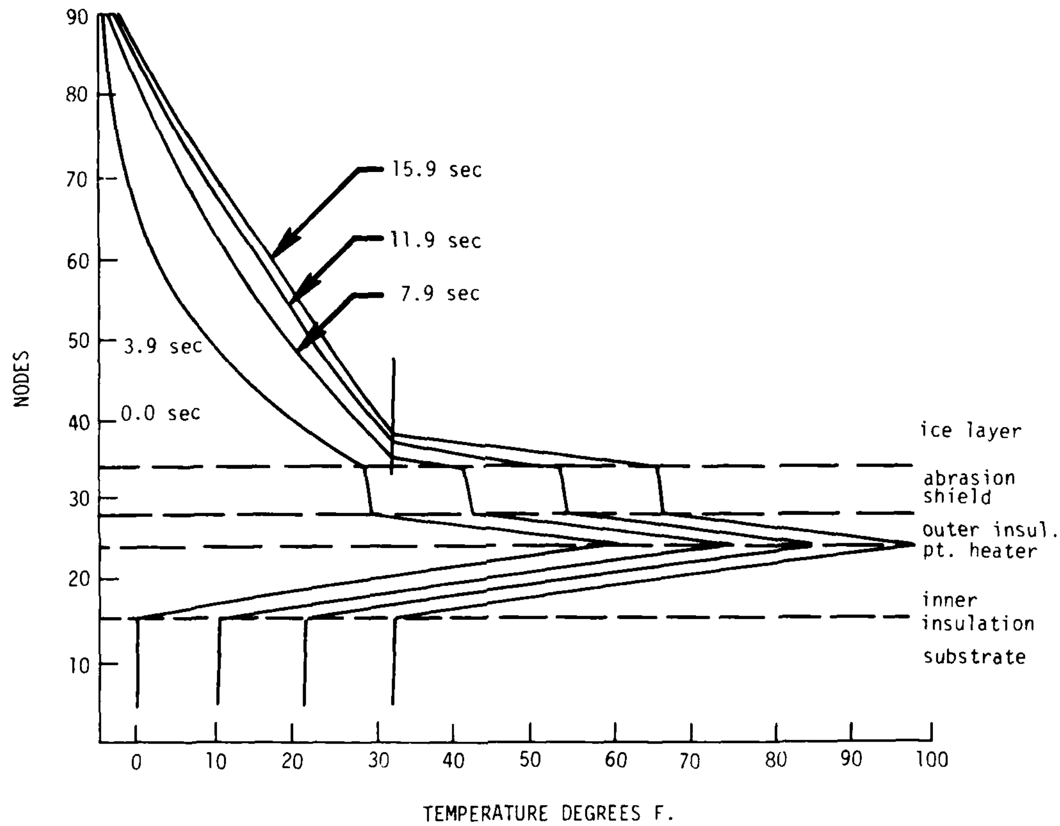

Figure 6. Temperature - time curves for point heater - phase change. (Heat input 25 watts/sq. in.)

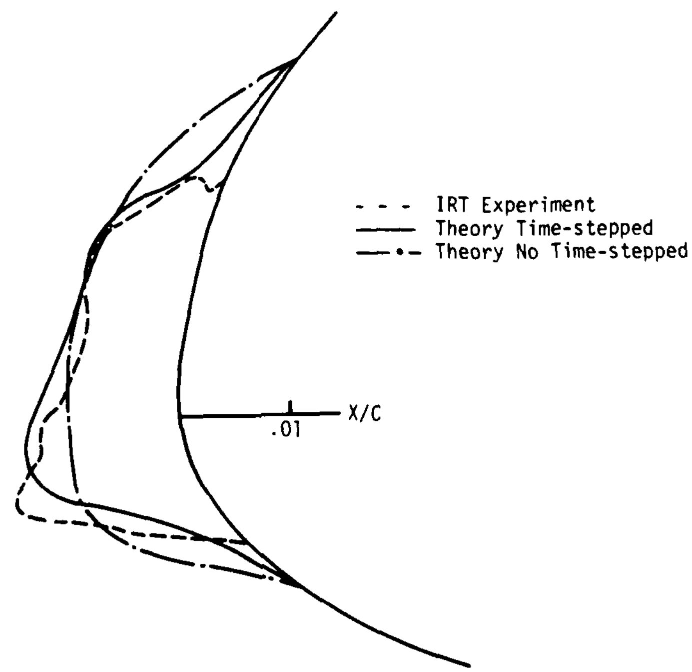

Figure 7. Comparison of theory to experiment. Modified NACA 64-215

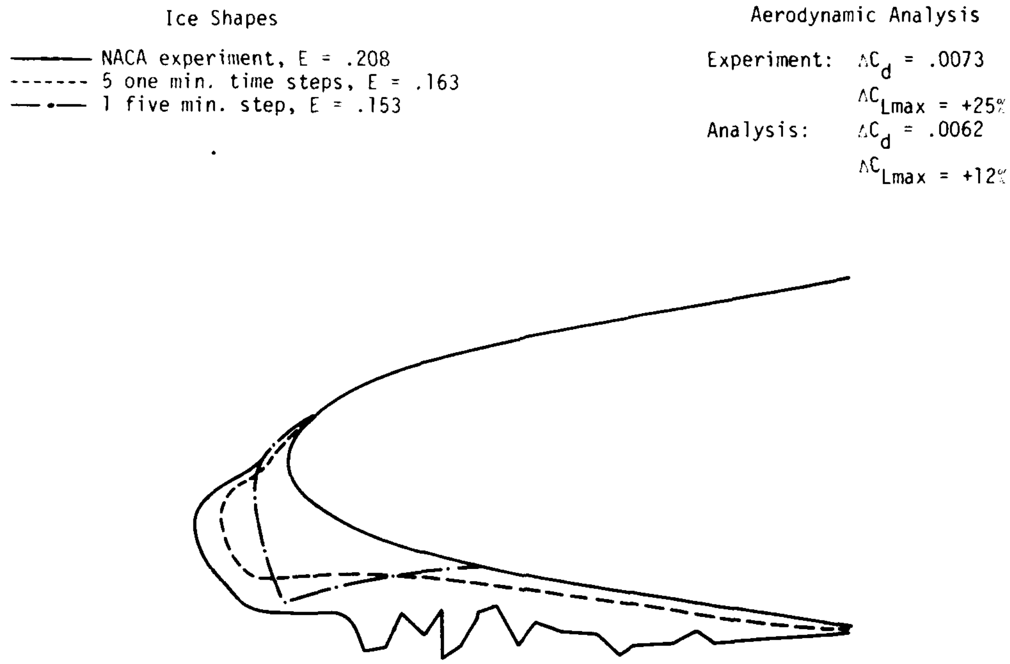

Figure 8. NACA 65A004 Icing analysis.

shown in Figure 8 in which the time-stepped results again show closer agreement with the experimental results. The aerodynamic results for both drag and lift coefficients are within reason taking into account that the code is not yet completely developed.

Currently, an analysis of the historical icing data below 10,000 ft altitude is being conducted at NASA/Lewis while modern and old cloud instruments are being compared in the NASA/Lewis Icing Research Tunnel in a joint program with the Air Force. Eight different laser spectrometers and rotating cylinders are being used to evaluate both droplet size and liquid water content measurements. The Leigh, J and W, and the PIRM blade are being used in liquid water content comparisons. A Rosemount outside air temperature device is being evaluated while General Eastern and EG&G relative humidity meters are also being used in the tunnel. Both the cloud data analysis and evaluation of cloud instruments are currently in progress.

NASA/Lewis has a contract with Ideal Research of Rockville, Maryland to analyze, build, and demonstrate a proposed microwave ice detector that will measure ice thickness and ice accretion rate (Figure 9). Breadboad tests at Lewis have shown the theory to agree quite well with the test results. The detector, which will be installed in a two-dimensional airfoil, will be tested in the Icing Research Tunnel in the summer of 1981.

A report has recently been issued by NASA/Lewis which describes the test program and results from tests conducted on a pneumatic deicer installed on a six foot rotor blade section. The blade was mounted vertically and stationary in the Icing Research Tunnel and was tested at velocities of 150 mph and 250 mph. The icing environment was characterized as having 1 g/m^3 LWC and 20 micron droplets. Two temperatures were selected to give both glaze and rime ice, 25°F and 5°F, respectively, and there were no dynamic loads on the blade.

The results showed that the drag penalties for the rotor with a deflated boot were near those of the clean blade, and drag penalties with the boot inflated are less than, or about the same as, the drag that results from a centimeter of accreted ice on the blade. The stall angle of attack of the rotor with the boot inflated was outside the normal region of rotor operation implying that accidental inflation of the boots on a typical installation should not produce detrimental results to the aircraft. Figure 10 shows a typical plot of section drag coefficient for the rotor-boot combination in which the rotor accreted ice at an angle of attack of 5.4 degrees and was deiced using the pneumatic boot at the same angle of attack. Both a glaze and rime ice condition were simulated at 250 mph. At the glaze ice condition the drag on the clean blade is shown to about 0.012. With one centimeter of accreted ice, the drag rose by 220 percent.

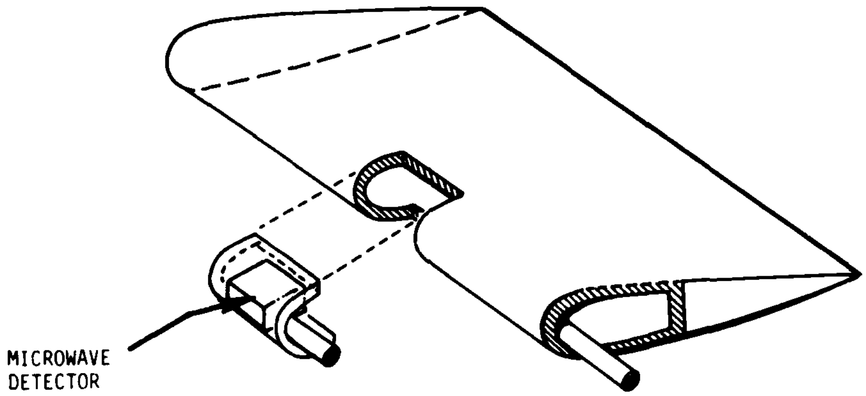

Figure 9. Microwave ice detector.

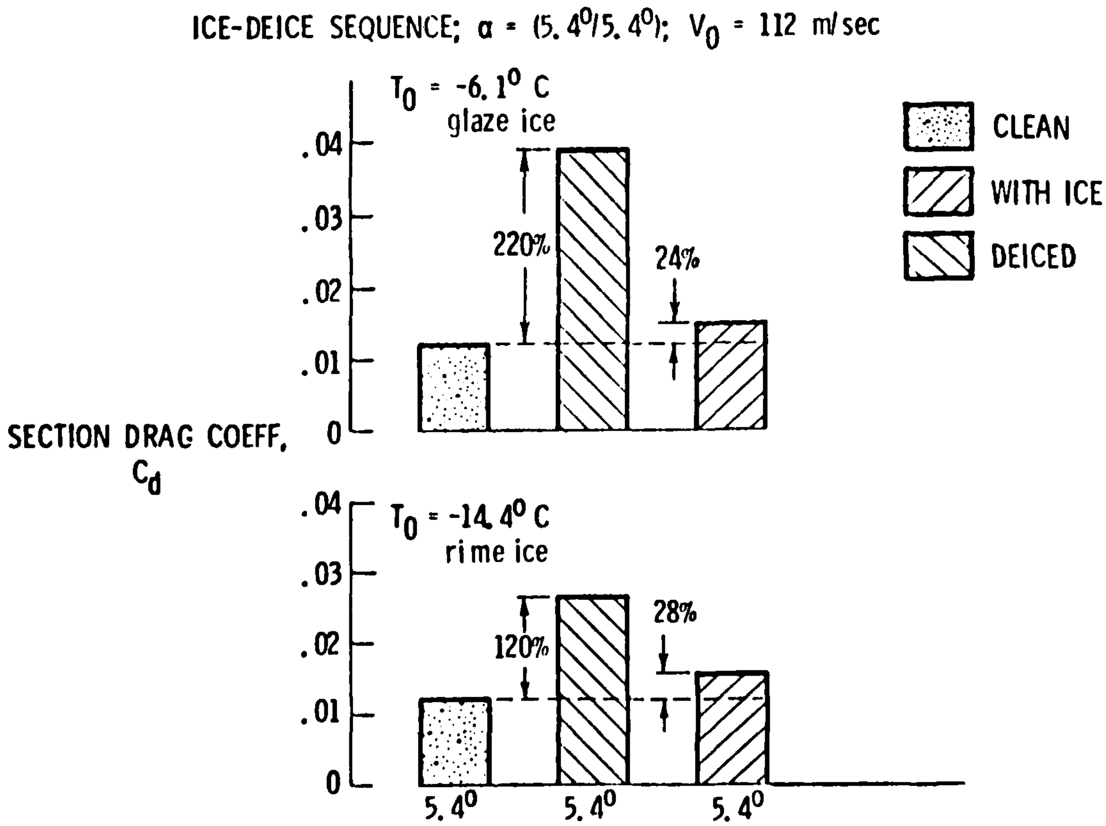

Figure 10. Section drag of helicopter rotor model with pneumatic boot.

After boot inflation, the drag was reduced to 25 percent over that of the clean blade. For the rime ice condition, the drag with one centimeter of ice rose 120 percent over the clean blade drag. Inflating the boot reduced the drag to 28 percent over that of the clean blade drag. Based upon these favorable results, a NASA/Ames-NASA/Lewis rotor pneumatic deicer test program has been established. At this time, deicer boots have been installed on a UH-1H rotor system, and instrumentation is being installed and checked. Next, a pretest safety verification will be conducted. Flight tests will follow in a non-icing environment, then, subsequent to favorable results, flight tests will be conducted in an icing environment.

Further tests involving rotor blades will be conducted in the Icing Research Tunnel using two test rigs being designed and built at NASA/Lewis. These include a rotating rig composed of an actual tail rotor and will be used to study ice shedding from rotors, evaulate icephobics on rotors, and to collect ice shapes for rotating blades. An oscillating blade rig, composed of a full scale rotor blade section, will be used to determine the effects that varying the angle of attack has on the ice accretion on rotor blades, to test pneumatic boots, and may also be used for fine tuning electrothermal deicers on rotor blades. Conceptual drawings of both rigs are shown in Figures 11 and 12.

In 1980 an icephobic material evaluation program was conducted jointly by the Air Force and NASA/Lewis. The objectives are to evaluate a number of candidate coatings for both rain erosion and ice release characteristics. NASA/Lewis designed, built, and developed the test procedure, and conducted the tests in the Icing Research Tunnel. The Air Force supplied funds to support material costs. A total of seven coatings were tested in the tunnel and the B.F. Goodrich rain erosion rig.

Figure 13 shows a schematic of a typical test specimen which consisted of an inner cylinder coated with the icephobic and covered by an

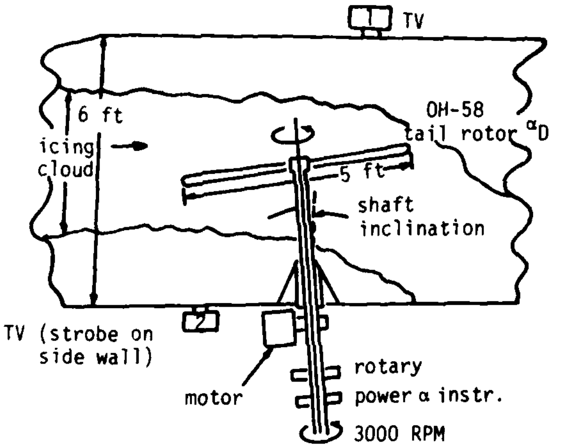

Figure 11. Rotating blade rig.

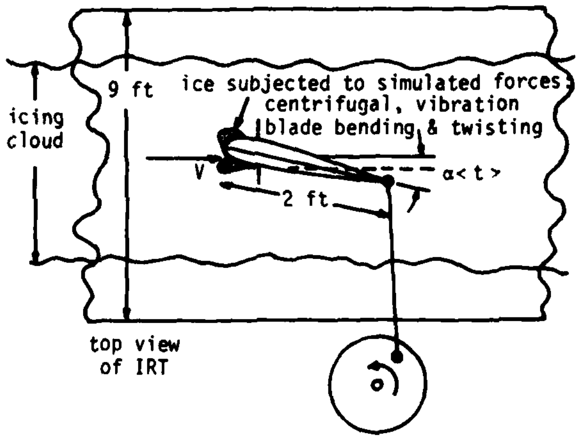

Figure 12. Oscillating blade rig.

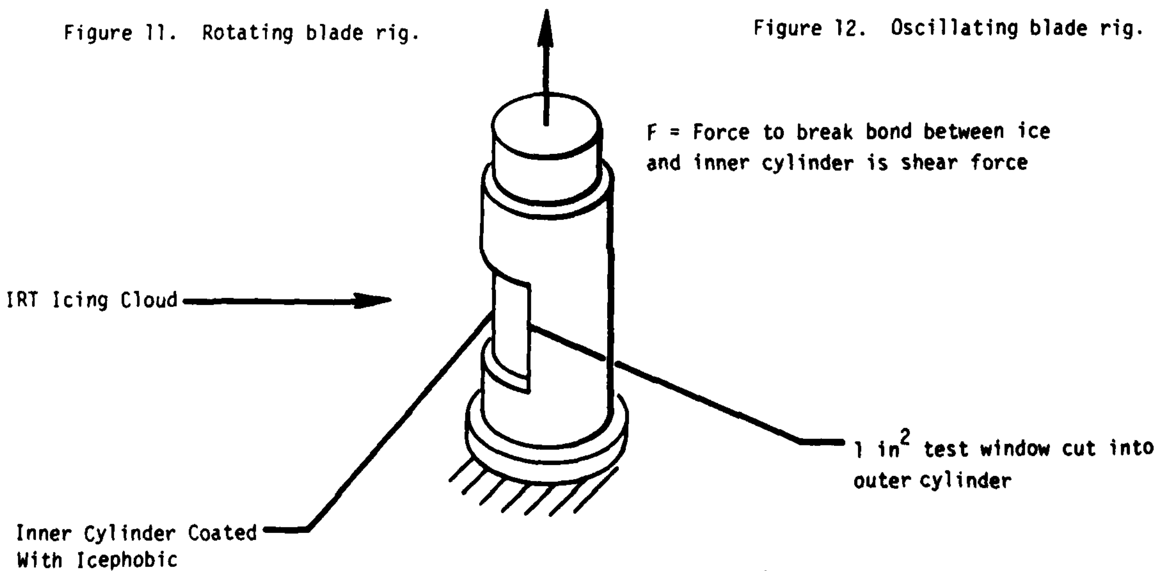

Figure 13. Ice adhesion test specimen.

outer shield which had a [illegible]
The test specimen was continuously rotated [illegible]
exposed to the icing cloud in the [illegible]
Tunnel. The outer cylinder was then [illegible]
tically relative to the inner cylinder. [illegible]
ice bond was broken from the [illegible]

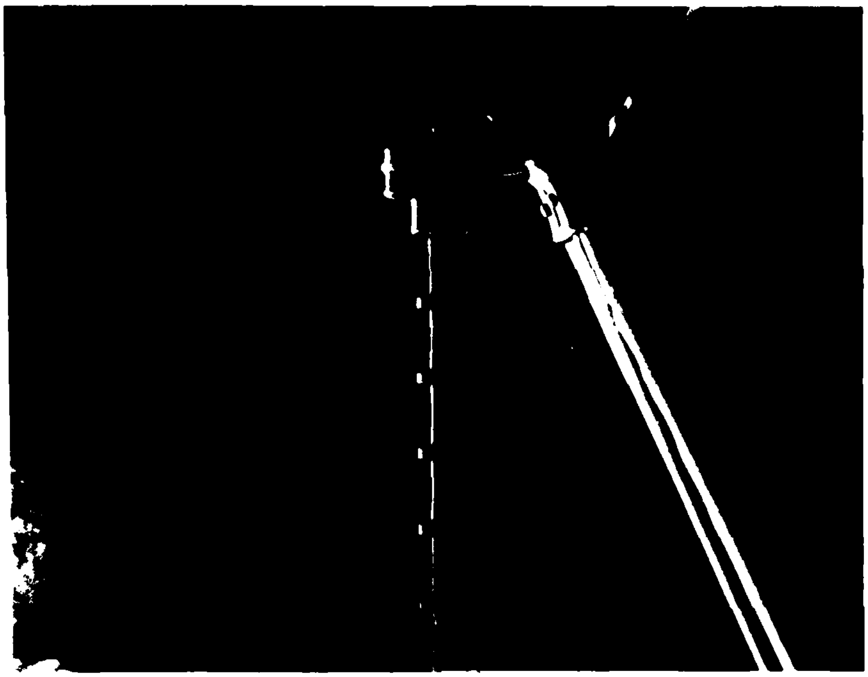

Figure 14. Test specimens in the tunnel.

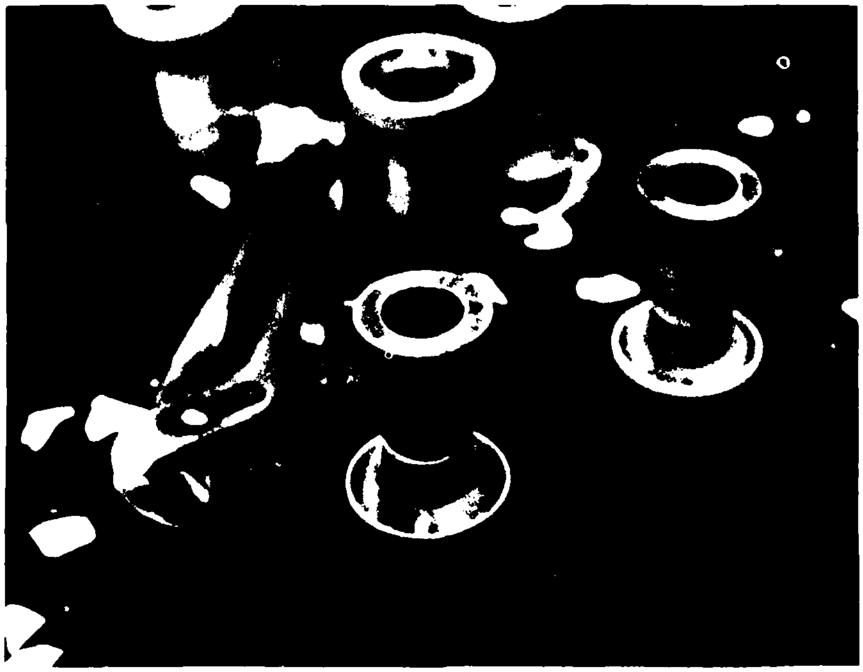

Figure 15. Test specimens following shearing process.

Data collected during the tests are shown in Figure 16 for three of the coatings and plain stainless steel. Two of the coatings have rather

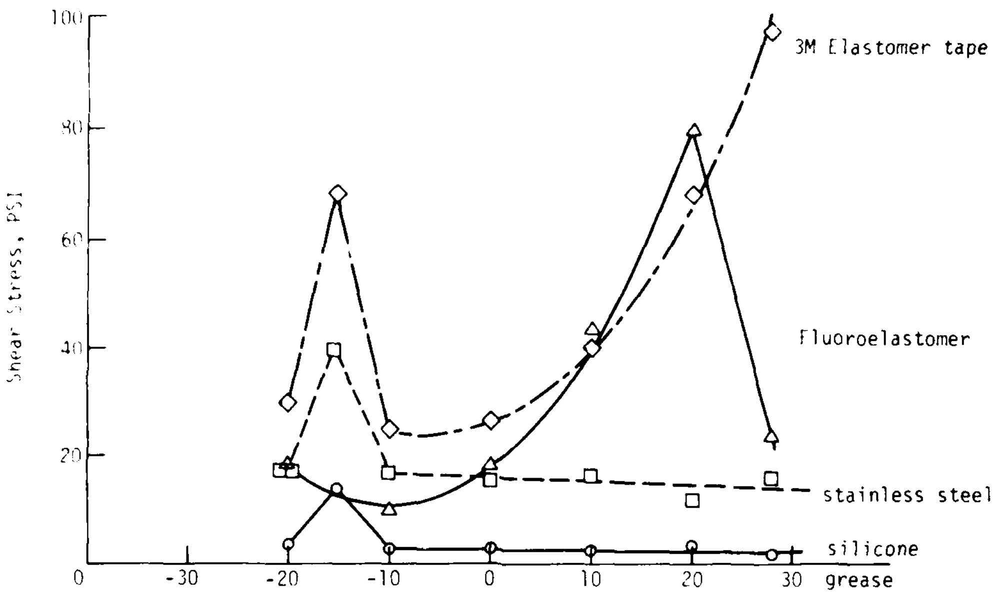

Figure 16. Shear stress vs. temperature.

high ice release characteristics while a General Electric silicone grease shows low shear forces required to break the ice bond in comparison to the other two coatings. Unfortunately, none of the coatings tested showed adequate resistance to rain erosion.

During pneumatic boot tests on an airfoil, Icex, which is manufactured for use on the boot, and the GE silicone grease were both used to coat sections of the airfoil as shown in Figure 17.

After one freeze-release cycle and two inflations of the boot, the silicone grease assisted in ice removal better than the Icex. However, as shown in Figure 18, after six freeze-release cycles, the silicone grease was completely worn off and did not contribute positively to the release of the ice.

Due to these results and in response to the recommendation of the general aviation icing study discussed earlier, NASA/Lewis has established a

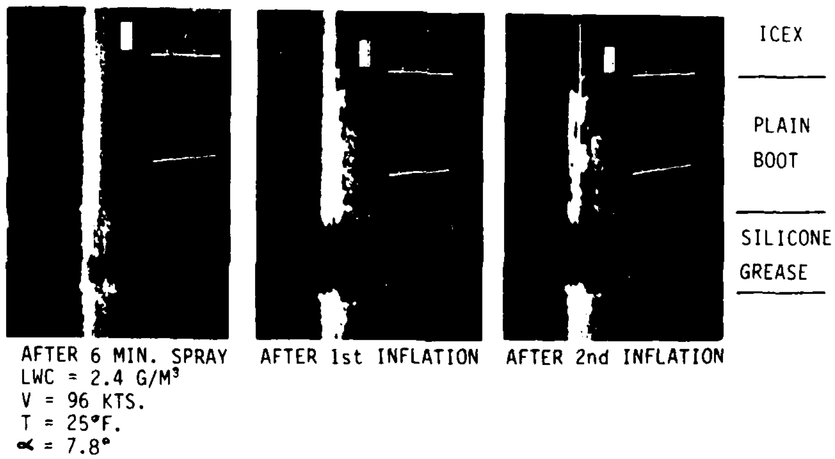

Figure 17. Illustration of the effects of combined pneumatic boot and coatings.

Figure 18. Illustration of the effects of combined pneumatic boot and coatings.

grant with Clarkson College of Technology to pursue the development of icephobic coatings for wings and rotor blades. The principle investigator is Dr. Hans Jellinek who in the 1970's developed an icephobic coating for concrete canal locks and has published over 100 papers and articles on polymer research. He will investigate the use of silicone oils and greases, block copolymers, and electrolytes in polymers as icephobics. The two criteria that must be met in the resultant icephobics are that they be effective ice release agents and be rain erosion resistant.

NASA/Lewis is also involved in a grant activity with the University of Kansas to investigate and compare two ice protection systems for general aviation aircraft. The systems will be compared on two typical general aviation airfoils. The ice protection characteristics of a TKS weeping glycol system with both stainless steel and composite leading edge porous panels will be compared with that of a pneumatic boot system on the same airfoil. Both systems will be evaluated in the Icing Research Tunnel at Lewis. The TKS system with a stainless steel panel was tested in 1980 of which an AIAA-81-0405 paper was published in January, 1981. A more detailed contractor report is being prepared that based upon this work will update the calculational techniques for fluid deicers currently found in ADS-4. The remaining TKS system tests and the pneumatic boot system tests will continue through 1981.

Figure 19 shows various stages of operation of the TKS system being used as both an anti-ice system (upper and lower third of panel) and as a deice system (middle third of panel). The airfoil was subjected to a five minute icing spray while the anti-ice protions were operating. As shown, both these portions are free of ice after the five minute exposure. The deice portion was then operated to remove the ice from the middle of the panel, and as shown, after three and a half minutes, the ice was nearly totally removed. Eventually, the wing was totally clean of ice.

That concludes the description of a number of recently completed and current research efforts in aircraft icing at NASA/Lewis. The Appendix gives additional information about these programs and other being planned by the Safety Technology Section at NASA/Lewis Research Center.

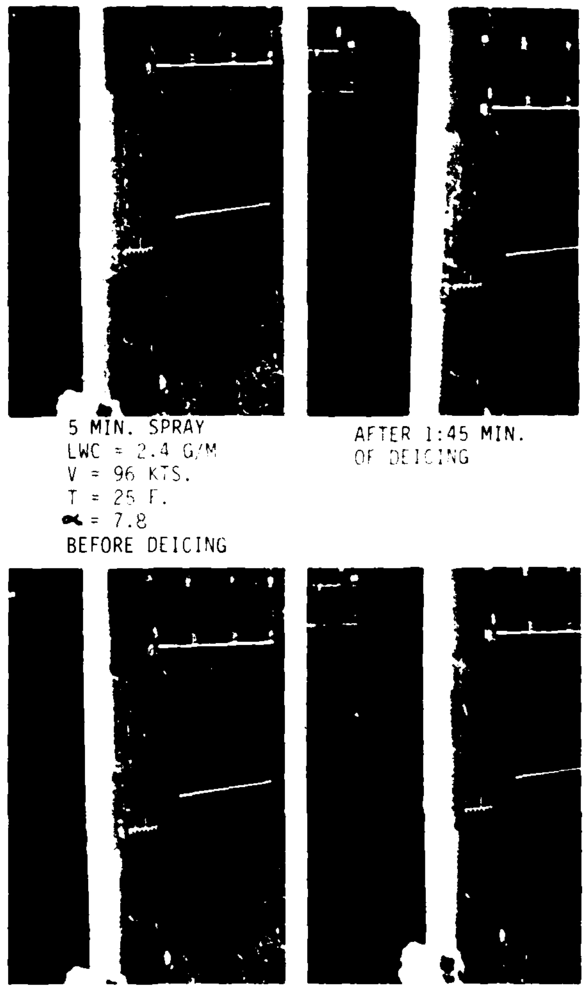

Figure 19. Operation stages of the TKS used as both an anti-icing and deicing system.

APPENDIX

ICING RESEARCH EFFORTS UNDERWAY AT NASA/LEWIS RESEARCH CENTER

1. LeRC is collecting all the old NACA icing cloud data-both that used to establish FAR Part 25, Appendix C, and later data-- for altitudes below 10,000 ft. Data will be entered on computer tape and sent to Mr. Richard Jeck at the U. S. Naval Academy.

2. Both modern and old instruments for measuring icing cloud properties are being tested in the NASA/Lewis Icing Research Tunnel (IRT). Performance of the various modern instruments (including several serial numbers of the same model) will be compared with each other and with the old instruments. (NASA/USAF program)

3. An oscillating two-dimensional airfoil rig will be installed in the IRT to determine the effect of varying angle of attack on ice accretion; to test pneumatic boot deicers for rotor blades; and to determine if, for electrothermal deicers, heater power levels and heater on/off times can be initially established in the IRT so that less flight testing will be needed to "tune up" the deicer system.

4. A rotating blade test rig will be installed in the IRT to determine its suitability for rotor icing resting; to determine the ice shedding characteristics of an OH-58 tail rotor coated with an icephobic; to determine the usefulness of the IRT for testing tail rotors; and to collect ice shapes from rotating blades for making artificial ice shapes and for comparing with analytical predictions. (NASA/ARMY program)

5. We are attempting to verify the published icing scaling laws for fixed (as opposed to oscillating or rotating) bodies, using both the NASA IRT and the USAF AEDC high speed icing tunnel. (NASA/USAF program)

6. From a modern (using "intrinsic reference variables") dimensional analysis of the governing equations for ice accretion, key non-dimensional groups are being determined for scaling ice accretion of both fixed and rotating airfoils. (NASA Grant with U. of Tennessee)

7. Transient 1-D and 2-D conduction heat transfer codes are being developed for analyzing electrothermal deicer systems, or other transient systems such as the proposed microwave deicer. The analysis includes conduction heat transfer through multi-layered structures within the airfoil, and heat transfer through the ice layer. These codes go a step beyond the conventional deicer analysis by including melting of the ice cap and a moving water-ice interface. The 1-D numerical model is completed. (NASA Grant with U. of Toledo)

8. We are developing a theoretical model that will predict the degradation of rotor/propeller performance in icing. Computer codes are being written for water-droplet trajectories in flows around rotor blades in hover. Ice build-up shapes will be calculated for rime ice conditions. Using both vortex theory and lifting line theory, the degradation of rotor/prop performance will be calculated in terms of efficiency, thrust coefficient, and power coefficient. (NASA Grant with Ohio State University)

9. We have a Grant to develop icephobic coatings for rotor blades and fixed airfoils. We have begun fundamental studies, both analytical and experimental, on the chemistry of icephobic coatings. Possible materials for basic studies include block co-polymers, self-healing films such as electrolytes in polymers, silicon oils and greases, and coatings which weaken the mechanical strength of the ice near the interface. (NASA Grant with Clarkson College)

10. We are developing a microwave ice accretion measurement instrument to see if it can simultaneously detect ice and measure its thickness and accretion rate. (NASA Contract)

11. We are testing a freezing point depressant fluid ice protection system that could have possible application to engine inlets or possibly to rotor blades, as well as to fixed wings, antennas, etc. The possibility exists to ooze fluids through porous composite materials as well as through porous stainless steel mesh. (NASA Grant with U. of Kansas)

12. We are developing a numerical ice accretion modeling code for rime ice, glaze ice, and conditions in between. This code forms the starting point in calculating ice accretion for analyzing deicer systems, for calculating aerodynamic performance penalties, and for making artificial ice shapes. (NASA Grant with U. of Dayton)

13. We are developing and will publish water-droplet trajectory codes for flow around 3-D lifting bodies, around 2-D lifting bodies, and flow through axisymmetric inlets at angle of attack (at the midplane) and flow through 2-D inlets. We have already published a code for 3-D non-lifting bodies. (Two NASA Contracts)

14. We are developing analytical methods to predict aerodynamic performance penalties caused by ice on 2-D airfoils. As a start, ice build-up shapes will be calculated for rime ice conditions, and the performance changes associated with the ice will be calculated. Experiments will be conducted in the NASA IRT to guide and verify the analyses. Eventually, these aerodynamic penalty predictions will be combined with

a more general ice accretion modeling code to predict performance penalties caused by rime ice, glaze ice, and conditions in between. (NASA Grant with Ohio State University)

15. We have developed an experimental rig for the NASA IRT to measure the interfacial shear stress for promising icephobic surfaces. We test, on a continuing basis, any materials that show promise of reducing ice adhesion forces. This is the only test facility that exposes the surfaces to simulated icing clouds under flight conditions.

16. We have a small in-house effort to study methods for separating particles out of engine inlet flows (inertial separators). Since inertial separation requires that the flow make sharp turns, boundary layer separation can occur resulting in poor pressure recovery. Our design experience on VSTOL inlets (high angle of attack) is directly applicable to the separator problem.

17. We are monitoring two grants (out of the Lewis Chief Scientist's Office) that provide basic heat transfer and thermodynamic data in support of our ice accretion modeling work. One grant uses napthalene sublimation methods to measure convective heat and mass transfer coefficents on the surfaces of artificial ice shapes. The other grant is examining the assumptions made in the derivation of the energy balance equation, and is studying the impingement, running, and freezing of single water droplets.

18. We have three study contract to establish the state-of-the-art in aircraft icing, to determine the icing R&T needs of the aircraft industry, and to recommend a short-term and long-term NASA Icing R&T program. The contractors are Boeing-Vertol for rotorcraft, Rockwell International for general aviation and light transport aircraft, and Douglas Aircraft for commercial aircraft.

EFFECT OF HEAVY RAIN ON AIRCRAFT

James K. Luers

The University of Dayton Research Institute

In the few minutes that I have, I'd like to do a couple of things. I cannot get into very much detail. There are three things that I can discuss. First of all, I will summarize what we have done in general terms on heavy rain effects on aircraft aerodynamics. Secondly, I'd like to go into some of the problems involved in validating our research. Finally, I'd like to discuss some wind shear accidents in which we think heavy rain may have been an important factor.

First of all to summarize what we've done. We've been working in heavy rain research for about two years. What motivated this research was our work in frost formation and what frost does to the lift and drag curves for an airfoil. If frost could cause severe aerodynamic problems for both general aviation and transport aircraft due to its roughness, then perhaps heavy rain could produce a similar result. That is, if an aircraft is embedded in heavy rain to the extent that the amount of water on the airfoil aerodynamically roughens the airfoil, then this would affect the turbulent friction coefficient of the airfoil as well as thickening the boundary layer. Drag increases and premature stall could result. In studying this problem over the past two years, we looked at what we felt were the influencing parameters of heavy rain on an aircraft (Figure 1).

The first one we examined was the raindrop momentum. When an aircraft enters a very heavy rain cell, the water that impacts the aircraft, assuming an inelastic collision, takes on the velocity of the aircraft. Thus, a momentum penalty can be calculated under reasonable assumptions. Under rainfall rates approaching 500 mm/hr., it becomes a significant factor. The weight penalty of the water on the aircraft can also be calculated. The thickness of the waterfilm on the aircraft is estimated and converted to a total water mass on the airfoil at an instant of time. This weight penalty can be shown to be negligible to transport category aircraft. We also think there is a moment force exerted on the aircraft. Rain impacts predominately occur on the leading edge of the airfoil and on the front of the fuselage. These impacts would produce a torque on the air-

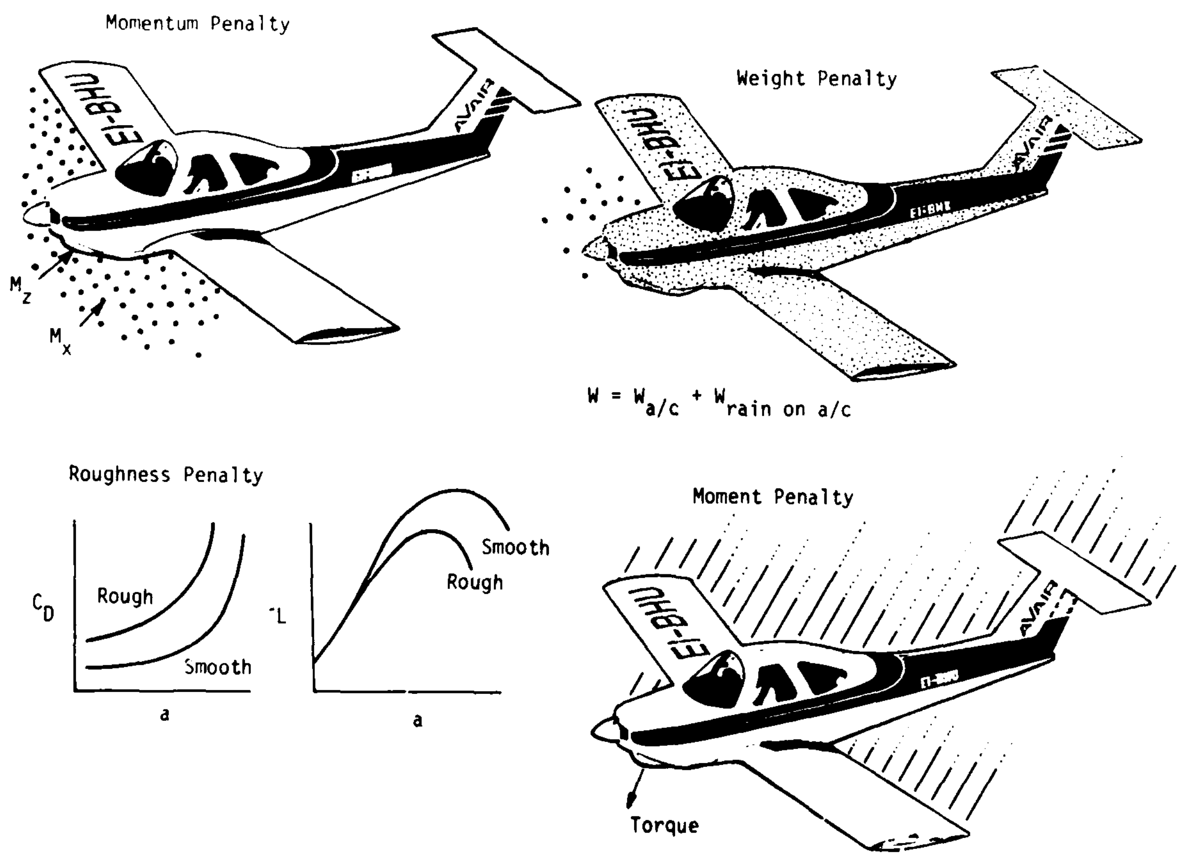

Figure 1. Effect of Heavy Rain on Aircraft.

craft. We have not determined whether it is significant. What we think are the most significant penalties are those due to a roughened airfoil. What you see in Figure 1 are typical lift and drag curves from the literature for fixed, sandpaper type roughness elements. These curves show that the drag coefficient for a roughened airfoil is larger at all angles of attack than for a smooth airfoil. The lift coefficient is also decreased, especially at high angles of attack. A decrease in maximum lift of ten to fifty percent can occur. In addition, the stall angle where maximum lift occurs is two to six degrees less for a roughened airfoil.

There are two components to the roughness penalty (Table 1). One is due to the waviness of the film; the other is due to the cratering of drops on impact. To model the waviness, one first has to calculate film thickness. In our research, we attempted to model, using the appropriate physics, the trajectory of the droplets that impact the airfoil at a given rainfall rate. We then did a mass balance for various sections of the airfoil in terms of water content so that we could determine an average film thickness for the airfoil. We calculated the film thickness on the airfoil and also related this to an equivalent sandgrain roughness. We used experimentally derived lift and drag curves based upon sandgrain roughness to convert to lift and drag penalties.

TABLE 1

SOURCES OF AERODYNAMIC ROUGHNESS DUE TO RAIN

IF WING IS WETTED WITH A THIN FILM
• Waviness of film
• Disturbance of film surface by drop impacts
IF WING IS NOT WETTED
• Water globules

The second component of roughness is due to drop impacts. When a drop impacts the airfoil, a crater forms and each crater produces a distinct roughness element. Those roughness elements also contribute to an equivalent sandgrain roughness. In modeling the cratering effects, we could not find experimental data upon which to validate our physical model. Experimental drop impact and cratering data exists for low velocity impacts but not for high velocity impacts. Consequently, we had to extrapolate Weber Number and other parameters to model high velocity drop impacts.

We derived an equivalent sandgrain roughness from both drop impact cratering and for the waviness of the film. We converted each sandgrain roughness to a corresponding lift and drag penalty. Significant drag and lift penalties on the order of five to thirty percent resulted.

To put things in perspective, we had to use a lot of assumptions. We think they are reasonable assumptions, but they have not been validated. Some of the things that we think are factors in validation are difficult to experimentally test in nature. First of all, one must have a sufficiently large rainfall rate to form a water film. If there is not enough water on the airfoil, no water film will occur - only rivulets. We do not know if there is a roughness penalty associated with rivulets. We think there is a critical amount of water needed to assure a water film.

The water film thickness depends upon the thickness and chord length of the airfoil. In general, other things being equal, a larger airfoil will have a thicker film. However, other things are generally not equal. Transport aircrafts land at higher velocities than smaller aircraft which tends to thin the water film. Thus, tradeoffs occur.

We think the leading edge slats are especially critical in increasing film thickness because of the increased presented area for water accumulations and because they present a surface whose orientation is nearly perpendicular to the direction of the incoming drops. We think the roughness penalty associated with an aircraft in the landing configuration with the high lift devices may be much greater than it is for the cruise configuration with high lift devices retracted.

Some of the accidents we have analyzed are shown in Table 2. These first five have been analyzed in detail. We think that heavy rain may also be a factor in the other accidents listed.

TABLE 2

WIND SHEAR/HEAVY RAIN ACCIDENTS

1.	Eastern 66/Kennedy	1975
2.	Eastern 727/Atlanta(Incident)	1979
3.	Allegheny DC-9/Philadelphia	1976
4.	Jordanian 727/Qatar	1979
5.	Eastern 727/Raleigh	1975
OTHER POSSIBLE WIND SHEAR/HEAVY RAIN ACCIDENTS		
	Salt Lake City	6/08/68
	Naha	7/27/70
	Ft. Lauderdale	5/18/72
	New Orleans	7/26/72
	Chicago	6/15/73
	St. Louis	7/23/73
	Chattanooga	11/27/73
	Pago Pago	1/30/74
	Houston	12/14/74
	St. Louis	11/29/75

We think there are basically two types of accidents that may be produced by heavy rain. One is primarily due to the drag penalty. In this type accident, a shortfall occurs in which the aircraft impacts prior to reaching the runway threshold. The Eastern 066 accident at JFK in 1975 and the Raleigh accident in 1975 are of this type. The other type is a go-around accident.

Table 3 describes the Raleigh accident. The wind observations near the accident time indicate light winds. These observations were taken very close to the scene of the accident. Very heavy rain was occurring.

TABLE 3

EASTERN 727 RALEIGH

November 12, 1975

The aircraft was on ILS approach in heavy rain showers. The aircraft struck the ground 282 ft. short of the runway.

Weather:
Not a thunderstorm. The rainfall rate was greater than 2 in./hr. In fact, 1.45 in. was measured in a one hr. period.

WINDS - OBSERVATIONS

t-7 min	160° at 5 kn	Moderate Rain
t+2 min	160" at 6 kn	Heavy Rain
T+7 min	190° at 8 kn	Heavy Rain

Figure 2 is a trajectory reconstructed from the flight data recorder as obtained from the NTSB report. The aircraft approached at a normal descent rate to about 200 ft where it entered rain of increasing intensity. According to the pilot, he added thrust at this point. His descent rate increased to 1200 ft per minute. At 100 ft, according to the Captain, "I ran into a wall of water, and the bottom fell out as I added thrust." His descent rate at touch down was 1400 ft per minute. We don't believe this was a wind shear accident. There does not appear to be enough horizontal or vertical shear to justify the increased descent rate. Yet, something certainly increased his descent rate from 700 ft per minute to 1400 ft per minute. We think heavy rain extracted momentum from the aircraft and dramatically increased its drag causing the aircraft to descend below the glide slope.

Table 4 summarizes our results. Table 5 illustrates the Atlanta incident - a thunderstorm, very heavy rain cell situation.

Figure 3 is the aircraft trajectory as extracted from the NTSB incident report. The aircraft is initially above the glide slope in a moderate rain. It then enters a very heavy rain cell, descends below the glide slope, initiates a missed approach, continues to descend, exits the rain cell, and finally starts a climb-out. The aircraft at about 800 ft began the execution of a go-around. Consistent with a missed approach, the aircraft rotated to 10 degrees nose up and takeoff thrust was applied. The aircraft, instead of climbing, continued to descend. The

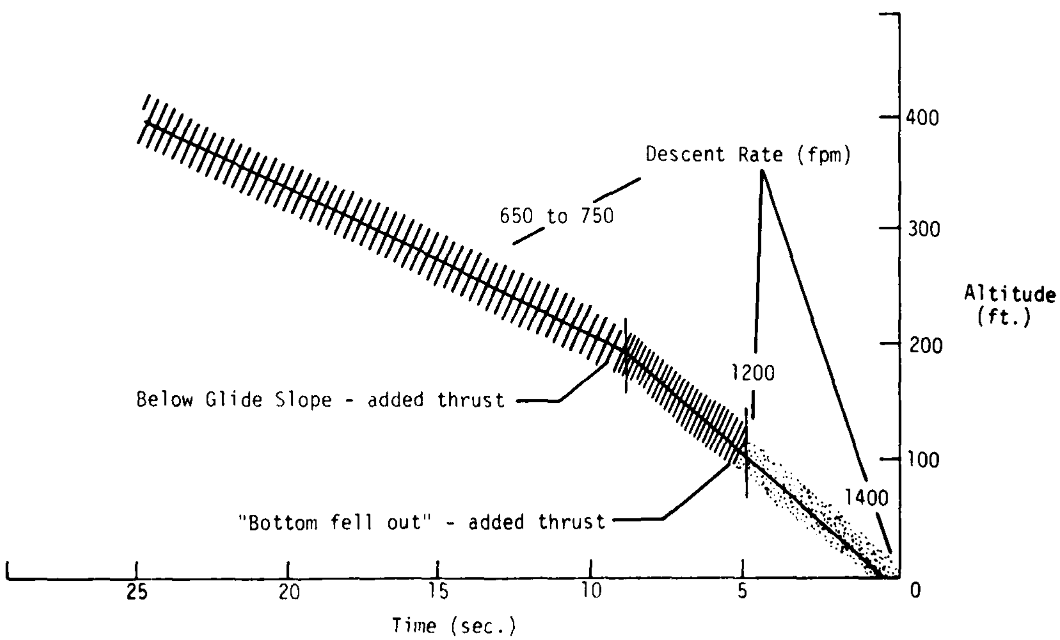

Figure 2. Flight Trajectory of Eastern 727 - Raleigh, North Carolina.

TABLE 4

EASTERN 727 RALEIGH

Analyses

NTSB ANALYSIS

- The aircraft, when entering a heavy rain, encountered downdraft and wind shear. Pilot did not increase angle of attack sufficiently to arrest descent.
- The Captain stated that at 100 feet he encountered a "wall of water" and that "the bottom fell out" as he added thrust.

METEOROLOGICAL ANALYSIS

- Based on meteorological analysis, no significant wind shear existed.

UDRI CONJECTURE

- Heavy rain dramatically increased drag and extracted momentum from the aircraft causing it to descend well below the glide slope. Increased drag reduced the effectiveness of increased thrust.

pilot increased the nose pitch up to 15 degrees and applied maximum thrust (overboosting the engines). His descent rate continued to increase. According to the NTSB report, the stall warning device activated. It remained activated for 10 to 20 seconds according to the pilot and the First Officer. The aircraft then exited the rain shower and began a rapid climb completing the recovery. The NTSB analysis concluded that the aircraft encountered a strong downburst region with vertical velocities on the order of 28 to 50 ft per second. Our explanation is that the aircraft stalled. For a roughened airfoil the stall angle can decreased by 2 to 5 degrees over that associated with a clean airfoil. The pilot would not be aware of the stall configuration because activation is based upon clean airfoil aerodynamics. The fact that the stick shaker did activate indicates that indeed the aircraft

TABLE 5

EASTERN 727 ATLANTA INCIDENT

August 22, 1979

The aircraft encountered a localized but heavy rain shower with associated wind shears on the final approach. The aircraft came within 375 feet of crashing before it exited the shower and a missed approach was completed.

Weather:
Very heavy rain cell. Athens radar reported Level 4 cell. Winds were variable and gusty. (Aircraft winds were derived from flight recorder data.)

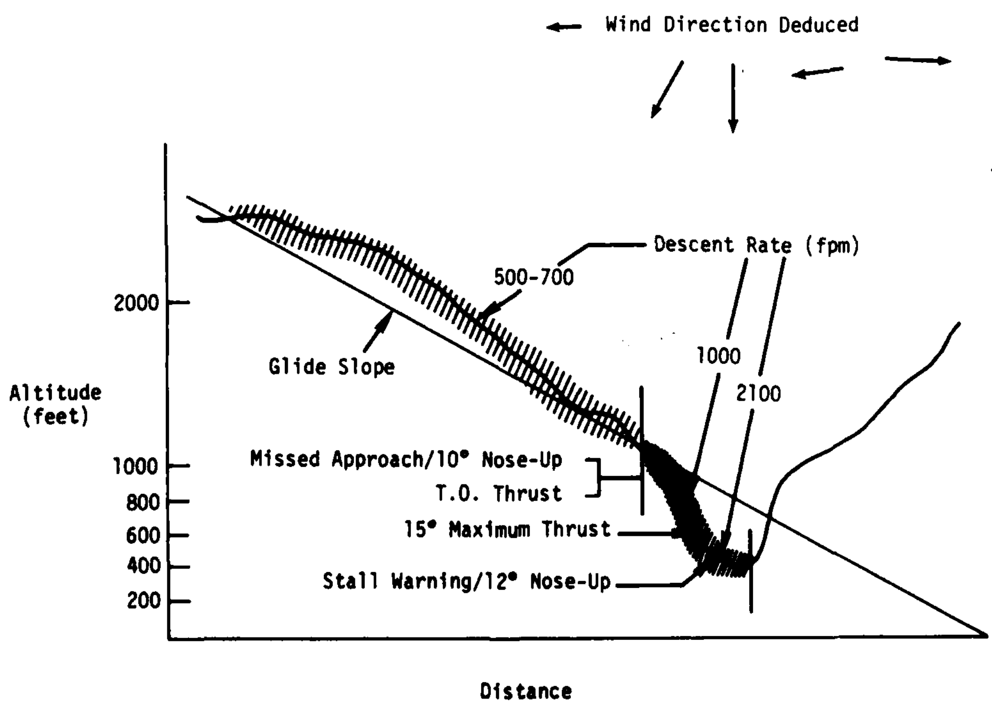

Figure 3. Flight Trajectory of Eastern 727 - Atlanta Incident.

was at a high angle of attack and with a roughened airfoil would be in a stalled configuration. We think there is an inconsistency between the stick shaker activation and the existance of a large downdraft. With a pitch angle of 10 to 15 degrees as indicated by both captain and first officer, the angle of attack could be sufficiently large to activate the stall warning device. If, however, the aircraft was embedded in a downdraft, then the vertically descending air was giving the aircraft its large descent rate. The aircraft may indeed have been rising with respect to the descending air mass. In this situation the aircraft's angle of attack would be small, perhaps 10 degrees less than its pitch angle. Since the stall warning activation is based upon a large angle of attack, we do not believe it possible that a downdraft could activate this system. On the other hand, using our hypotheses that the aircraft has stalled due to a roughened airfoil, there is no inconsistency. The aircraft would be at a high angle of attack which would activate the stall warning system.

Tables 6 and 7 summarize our results from the Atlanta incident.

TABLE 6

EASTERN 727 ATLANTA INCIDENT

NTSB ANALYSIS

- The aircraft experienced an extreme downburst, on the order of 200 to 3000 ft./min.
- The downburst cell lasted only minutes.
- FDR and aircraft performance capabilities indicated that the nose had to be lowered to 0 degrees at one time.

HOWEVER

- The wind structure was unusual for a downburst, in that the aircraft did not experience a tailwind on exiting the downburst.
- The downburst was not detected by weather sensing instruments.
- Delta 128, 1 minute behind, did not encounter significant wind shear.
- The Captain and First Officer did not observe any pitch angle less than 10 degrees.

TABLE 7

EASTERN 727 ATLANTA INCIDENT

UDRI CONJECTURE

The aircraft entered heavy rain ana mild downdraft. The rain produced additional drag and momentum penalties which caused the aircraft to descend below the glide slope. When the decision for the missed approach was made, the aircraft was raised to 10° nose-up which increased momentum and drag penalties and did not produce the necessary lift increase due to roughened airfoil. The aircraft rotated to 15° nose-up. The stall warning went off, but the aircraft had already stalled due to a possible 30% lift penalty. 15° nose-up also increased drag and momentum penalties because of a larger presented area. The aircraft existed the rain and instantaneously, drag, momentum, and lift penalties disappeared. The aircraft was no longer stalled. The aircraft accelerated and began to climb.

Prototype Regional Observation and Forecast System (PROFS)

John W. Hinkelman, Jr.

FAA Representative to PROFS Program Office *

Introduction

The PROFS Program is a unique NOAA capability that links atmospheric research (RD) with operations (OAS). This uniqueness results from several important program characteristics:

- Objectives are developed jointly between RD and operational components.
- The program is staffed by people from ERL, NWS, and other agencies interested in advanced weather service design.
- There is a strong interaction between systems design activity, technical development, and forecast office operations.
- PROFS interfaces with research groups that develop advanced atmospheric measuring devices and forecasting techniques (OWRM, NSSL, WPL, NWS Laboratories, NCAR, University of Wisconsin, CSU, and AFGL).
- A unique test, evaluation, and design demonstration facility (the EDF) is used to examine individual components and optimum system combinations.
- PROFS regularly sends elements of its mesoscale data base to other ERL groups, to the Colorado State Climatologist, and to SERI for use in advanced forecast technique and energy related research.
- The program facilities are directly linked with local operations at the Denver WSFO and the FAA Regional Air Traffic Control Center in Longmont, Colorado.

PROFS' outputs are demonstrated, functional design specifications that the NWS and other agencies can use to procure and implement operational systems. Advanced candidate technologies are thoroughly evaluated as an integral part of the process that leads to these outputs. Such evaluation of components helps to insure that future weather service systems will contain the optimum mix of technologies to be most cost-effective in reducing the annual losses of $2 billion and 600 deaths that are directly attributed to severe weather. The recommendations that stem from such evaluations also provide important guidance and input to NOAA's long-range plans.

*Present Affiliation
Chief, Interagency Coordination and Product Implementation
PROFS Program Office
NOAA/ERL
Boulder, Colorado

In this summary we outline the accomplishments during the first one and a half years of the program, review its status, describe a new evaluation methodology and the flow of new technologies through our design process, and finally preview our plans for the remainder of Phase I and beyond.

Accomplishments

Phase I objective is to design, evaluate, and demonstrate a first incremental improvement to the existing NWS field office capability by exploiting advanced interactive processing and combinations of existing data sets for use in preparing severe storm watches and warnings. This unique approach is setting objectives for a NOAA program stresses the importance of meeting critical operational requirements, but does not overlook the major impact promised by more advanced systems such as Doppler radar, VAS, and the Profiler. The first phase objective stresses that the design must anticipate the introduction of these new technologies, and that they are to be fully evaluated and integrated during later phases.

Staff:

The program started in FY 80 with a staff of six, drawn from other ERL groups. We now have 65 people from ERL, NWS, FAA, and contract support, distributed among the program elements shown in Figure 1.

Each group within PROFS addresses a specific aspect of advanced design transfer from research to operations. System Analysis and Design emphasizes the need for a total design approach that considers interfaces, communications, and engineering criteria in meeting the stated operational requirements. The Exploratory Development Group provides programmatic interface with the research community by selecting, tailoring, and evaluating new technologies for integration into the total system design. The Exploratory Development Facility evaluates and demonstrates new designs. This facility has been built with the flexibility to accommodate everything from the simplest sensor to more complicated Doppler radar and mesoscale numerical models, and to hourse a complete real-time operational model of complex local-scale service system designs. The Test and Evaluation Group acts as a final internal check point to insure that the recommended designs meet specified standards before they are handed off to operations for implementation. The Interagency Coordination Group insures that other agencies with interest in and requirements for local-scale weather services are represented in the design process.

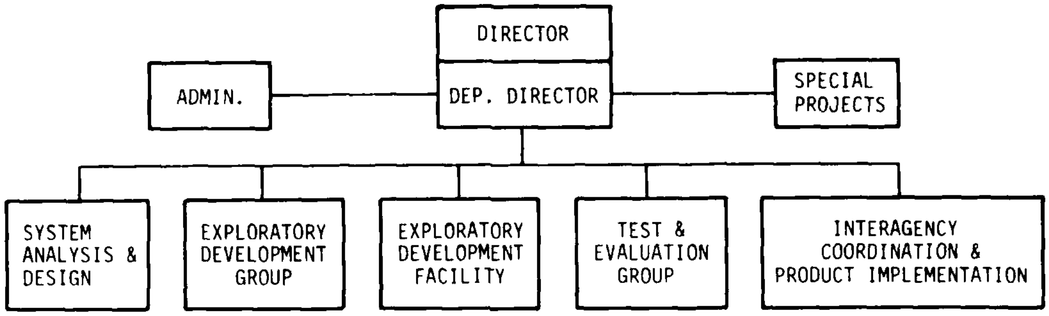

Figure 1. PROFS Internal Organization.

The internal organizational structure covers the essential functional areas, but the true strength of the Program comes from the direct involvement of people from both research and operations. Two of the senior line managers have been detailed to PROFS (ERL) from the NWS and another is from the FAA. This direct working-level participation by representatives of service-oriented groups helps to insure that the final products will be directly relevant to operational needs.

Facilities:

The major elements of the evaluation and demonstration facility (the EDF) are shown in Figure 2. Acquiring live satellite data from Colorado State University (40 miles from Boulder) involved close coordination between university and PROFS staff. Working closely with NWS we have established direct links to the Limon and Cheyenne conventional radars. A precedent-setting agreement with NCAR makes the NCAR-owned and operated CP-2, 10-cm Doppler radar available to PROFS starting in October 1981. Doppler radar data processing capability is part of the NCAR agreement and is housed in the EDF. Through such cooperation we have managed to implement the EDF nearly a year sooner than originally planned.

The PROFS unique surface mesoscale network came on line in early 1981. Similar networks have been established for short-term field experiments, but the PROFS system automatically provides mesoscale density surface data year-round.

Conventional data are collected through an operational AFOS link and an AFOS forecast office unit. (This unit, scheduled for a weather service field office installation, was redirected to PROFS by the NWS). The EDF is also now ready to accept data from advanced sensors. Data from the NCAR 10-cm Doppler radar will be introduced by the end of this year; VAS data can be collected via existing satellite links, and we are ready to collect Profiler data as soon as the system is on line.

The processing portion of the EDF is a major computer facility. By the end of FY 81 it will contain two DEC VAX 11/780's, one VAX 11/750, and five LSI 11/23's. Software for the 1981 Exercise is in hand and in use. A top-down soft-

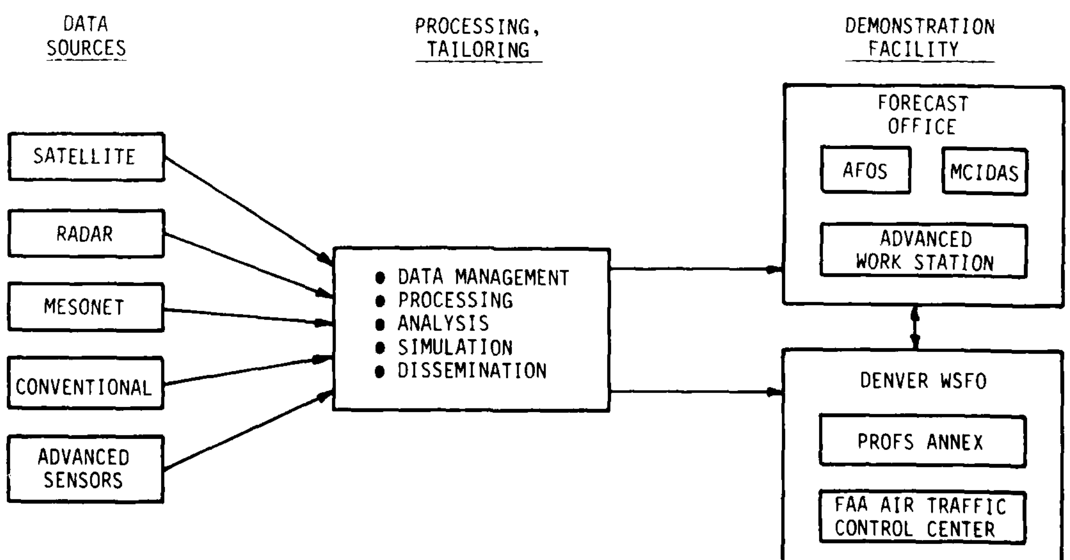

Figure 2. The Exploratory Development Facility (EDF).

ware design to support real-time operations and displaced real-time (or record and playback) experiments during FY 82 is underway and will be implemented by Spring 1982.

The forecast office in the EDF is also unique. Nowhere else can functioning AFOS, MCIDAS, and advanced VAX-driven RAMTEK workstations be found side by side. The 1981 Exercise will be the first inter-comparison of the interactive processing and display capabilities of these advanced forecaster workstations.

The EDF real-time data base and prodcut generation capability will be linked to the Denver WSFO and the FAA Air Traffic Control Center before the end of 1982. The FAA is already planning experiments that will use the data and products transmitted on this link to develop more effective air traffic control procedures.

Present Status

Staff:

Ninety percent of the required staff is now onboard. Forecasters from NWS, USAF, universities, and the private sector will participate on-site during the 1981 Exercise. We have also achieved international participation with the one year assignment of a Dutch Weather Service meteorologist to PROFS in Boulder, and we have been invited to assist the Swedish Air Force in setting up a PROFS-like program in Sweden.

Activities:

The EDF is now configured and is being used for the 1981 Exercise. Equipment needed to support the 1981 Exercise is being installed. The top-down 1982 EDF software design is fifty percent complete and will be ready for implementation this winter.

Flow of New Technology Through PROFS

To achieve an orderly and more rapid flow of technology from the research community to the operations community, it is generally accepted that we need a three-tiered evaluation structure that starts with testing elements, evolves through tests of system concepts, and ends with total operational evaluation. We now have the capability to perform these functions for interested service agencies.

A technique or device qualifies for entry to the process by under-going proof-of-concept--the researcher has validated parametric relationships, established an acceptable level of reliability, and adequately documented his work. Once qualified, the technique is physically interfaced with the EDF for evaluation as a stand-alone element.

Next, the technique or device is operated in displaced real-time as the relative value of each element to the forecast is measured. Cost/benefit trade-offs are also considered.

Finally, the system (that by now may contain several new technologies) is evaluated by forecasters in a true operational environment. The evaluation and system description are then handed off to the operational community which has the responsibility for procuring and implementing the new systems.

Figure 3 shows both the flow and time frame for many of the technologies that are already going through the full evaluation process within PROFS. By monitoring the process the designer of a field system for any given year has a firm grasp on the items which have undergone real-time operational evaluation, can anticipate those items undergoing system concept evaluation, and must be highly speculative about the items in element evaluation.

	FY 81	FY 82	FY 83
TRANSLATION INTO OPERATIONAL ENVIRONMENT			
OPERATIONS INTERFACE			
REAL-TIME OPERATIONAL EVALUATION			
SYSTEM CONCEPT EVALUATION	1/2 HOUR CONVENTIONAL DATA LIMITED EXTRAPOLATION MODELS MCIDAS, AFOS, PROFS WORK STATION EVALUATION WATCH/WARNING PRODUCTS		
ELEMENT EVALUATION	EXPANDED CONVENTIONAL DATA SETS OBJECTIVE ANALYSIS COMPOSITE GRAPHIC IMAGES, OVERLAY TECHNIQUES WATCH/WARNINGS DISSEMINATION SYSTEM	PROFILER DOPPLER REFLECTIVITY VAS-SPECTRAL IMAGING PARAMETER MODELS STATISTICAL MODELS FULL INTERACTIVE TECHNIQUES EXPANDED DISSEMINATION	PROFILER DUAL CHANNEL DOPPLER WINDS VAS SOUNDINGS OTHER GEOGRAPHIC REGIONS HUMAN FACTORS INFORMATION ENHANCEMENT EXTERNAL USER DATA BASE
PROOF OF CONCEPT			
RESEARCH			

Figure 3. Flow of Technology.

The entire evaluation flow demonstrates that PROFS is a continuing process providing not a single system design, but a continuing analysis and evaluation of solutions to weather service problems.

A New Evaluation Methodology

The description of the technology flow through PROFS (Figure 3) is deceptively simple whereas the design and evaluation of short-range forecast systems form a large and complex problem because of the many uncertainties that are inherent to atmospheric processes. Classic system design methodology, whereby the needs of the ultimate user determine the dissemination, forecast, and data requirements, can be a useful starting point. But to that beginning, we have added an innovative evaluation methodology.

Once the design concept is developed, we must then ask what is really needed to make a good forecast. Using the excellence of a forecast as the measure of design quality, we can evaluate the elements of the forecast system as variables that may or may not contribute to a

good forecast. This method could be applied to existing synoptic-scale services that have been in operation for a long period. Records of forecast output prior to the introduction of a new device or technique could be compared with the output that followed. The length of record for this kind of performance examination would need to be very long to insure that a statistically significant number of each type of weather event has been forecast by many different meteorologists.

Since no mesoscale-oriented service now exists, we have no historical record that can be used to evaluate a short-range forecast system. We can, however, artifically generate such records in a relatively short period. This approach can then be adapted to provide solid evidence of the worth of various mesoscale-oriented system elements. To do this, we must first select the most difficult class of forecast; for example predicting the affected area and lead time for severe storms. Second, we assume that if a system is designed to produce this forecast, then it can effectively handle less challenging situations. Third, we create a quasi-operational forecast office that contains as many data sets as possible, workstation configurations, and other necessary and potential system elements. Fourth, a complete data base for many events (both severe and fair weather) must be collected. Finally, these data are played back to a large number of different forecasters while one or more of the key elements is either provided or not provided until a statistically significant sample is created. The impact of a given data set or forecast technique can then be examined in terms of the size of the warning area and forecast lead time.

This black box approach--where the output of the box (the forecast system under test) is affected by various inputs--provides significant information for the system designer. This will be the primary method used during the system concept stage of PROFS evaluations. It does not replace the need for real operational evaluations, but will provide many answers that will greatly increase our confidence that the final operational configuration is near optimum.

Plans

Our plans are best considered in three stages: immediate, near future, and long-range.

Immediate---1982:

1. Increase the EDF capability through introduction of real-time hardware and software capability, Doppler radar, Profiler data, and greater ingest rates of conventional satellite and radar data.
2. Conduct our first real-time operational evaluations at the Denver WSFO and the Longmont Regional Air Traffic Control Center.
3. Collect additional meteorological data sets that include Doppler radar and Profiler information for use in more complex displaced real-time testing.
4. Continue displaced real-time evaluations, using the new meteorological sets to extend our knowledge beyond workstation environment and into an examination of specific sensor performance, forecasting techniques, and integrated systems.
5. Complete the preliminary functional design specifications for our Phase I objectives in preparation for implementation and demonstration of the design during 1983.

Important sub-objectives that either support these major activities or strengthen the program include the following:

1. Develop an effective interface with the JAWS project and strengthen interactions with other ERL groups, universities, and other agencies such as DOD.
2. Encourage the use of the facilities by groups that have a direct interest in weather service system design and evaluation.

Near Future---1983:

During 1983 we will complete the Phase I objectives. That is, provide the functional specifications for a system that will:

1. Enhance NWS severe-weather and flash flood warning services by adding the capability to combine data and products from conventional radar, satellite, and surface networks, and that is field office compatible.
2. Add the capability to interactively display and manipulate the data sets.
3. Disseminate appropriate information rapidly.
4. Anticipate the introduction of future systems such as Doppler radar, VAS, and the Profiler.

Long-Range---1984 and Beyond:

The PROFS Program was conceived as an experiment that would strengthen NOAA's service role by increasing the efficiency with which research products are made available to operations. The resulting interdisciplinary unit was created with strong ties to both research and operations. This unique national facility that can evaluate and demonstrate a wide range of new technologies and integrated systems for improved weather services is nearly complete.

The cost of procuring and implementing operational components or field systems can easily

reach $100 million. NOAA has thus far invested about $8 million in PROFS. Potential savings on just one enhancement to operational services, which can be achieved through systematic evaluation before critical procurement decisions are made, can more than offset that initial investment in PROFS. PROFS now can provide functional specifications for advanced designs and, thus, insure the highest possible benefit-to-cost ratio for services provided.

Our specific long-range plans are to continue to:

1. Analyze and respond to operational requirements;
2. Create and evaluate advanced weather service functional specifications;
3. Demonstrate conceptual designs;
4. Conduct operational evaluations; and
5. Provide input to NOAA's long-range planne··

CABIN OZONE AND TROPOPAUSE DEFINITION

Arthur D. Belmont

Control Data Corporation

In the time available, I'd like to say a few words on the current status of the cabin ozone problem and the prospects of forecasting ozone at flight altitudes. Quantitative forecasting of local or total ozone is not yet available, but total ozone values can be provided in a nowcasting mode using satellite observations. As larger planes try to get better fuel economy, they fly higher into the lower stratosphere where ozone increases rapidly with height. Ozone is very toxic in concentrations near 5 ppmv, and the FAA has a rule effective February 1982 that planes must not have more than 0.25 ppmv in the cabin. The problem is that no one has ozone instruments on-board, has learned to estimate ozone at flight altitude, or is given any ozone forecasts along with the usual meteorological variables.

At CDC we have been developing a method to estimate ozone profiles. The profile technique is based on knowing the total ozone which may come from any observational system available such as Dobson photometers that are available from NMC forecasts and used operationally in flight planning. From this we can get an ozone profile at selected pressure levels. The technique was based on five years of ozonesonde data, 1970-1974 with the following results from independent data. Only one good and one poor example, and the statistical average error for all cases can be shown now. In Figure 1, the vertical scale is pressure altitude and the horizontal scale is ozone in a unit called nanobars (nb) which is what atmospheric chemists use. Just accept it as a relative scale. The dashed line on the left is the climatological average at Goose Bay at 53°N. The solid line to the right is the observed profile. The dotted profile is the estimated one, and the agreement is very good. What is especially interesting here is that normally the maximum ozone is at a higher altitude, but in this case, the maximum was much lower than usual, and our technique was able to detect it.

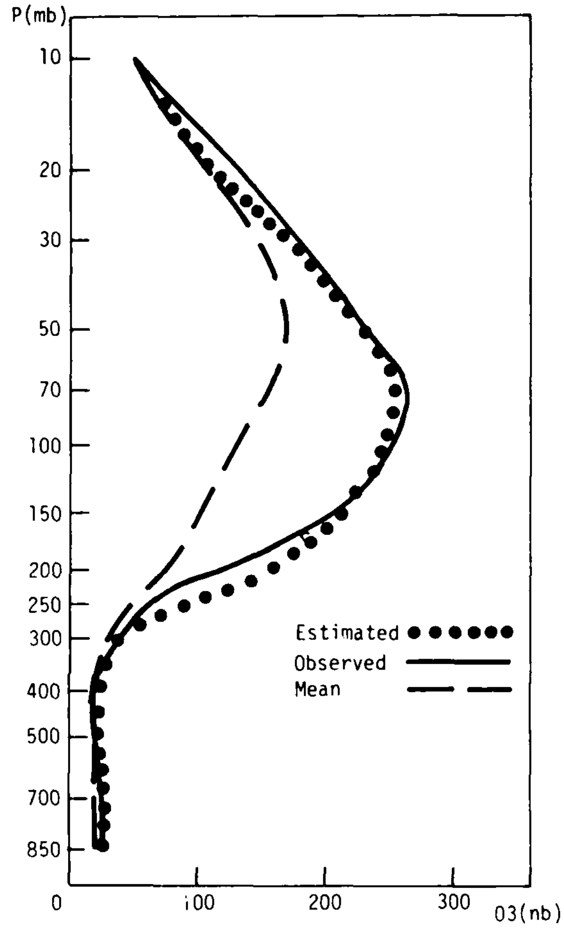

Figure 1. Validated ozone profile. Goose Bay (53°N. 300°E) 2/19/79 11Z TOMS = 527 M-AIM-CM.

Figure 2 is for a station in Germany where there were two maxima in the vertical (solid line). The climatological average is the dashed line, and our estimate was the fairly smooth dotted line that approached the lower and upper maxima but not the minimum. From the point of view of avoidance of ozone by aircraft, that need not be a disadvantage. It is not now possible to pick up the very small-scale features because the available NMC data is very large-scale, but the small features are not the ones that are really important for cabin ozone as it would be when you fly across a deep cyclonic system that has high ozone concentration. Such a large scale would be seen in the NMC--scale forecast data. Small or mesoscale variations are of no real consequence as they are quickly flown through.

So far, we have developed models for winter, spring, and fall but not for summer. We are hoping to introduce them operationally into flight planning. We could provide an objective computer algorithm that would estimate ozone along the flight path together with all the other NMC output. Improvements are possible, and if we can obtain support, they could be incorporated. We could use a larger data base and also look into the cases of individual extremes. The one problem that remains is quantitative forecasting of total ozone. No one, to my knowledge, has a way of doing this yet, although qualitative forecasts are easy. In the meantime, we hope our model can be applied in real-time for nowcasting, using the TOMS data that NASA/Goddard is now providing to Nor hwest Airlines a few hours after observation. The TOMS satellite data give the detailed horizontal variation of total ozone which is the amount in a vertical column of the atmosphere. Our method gives the vertical dis-

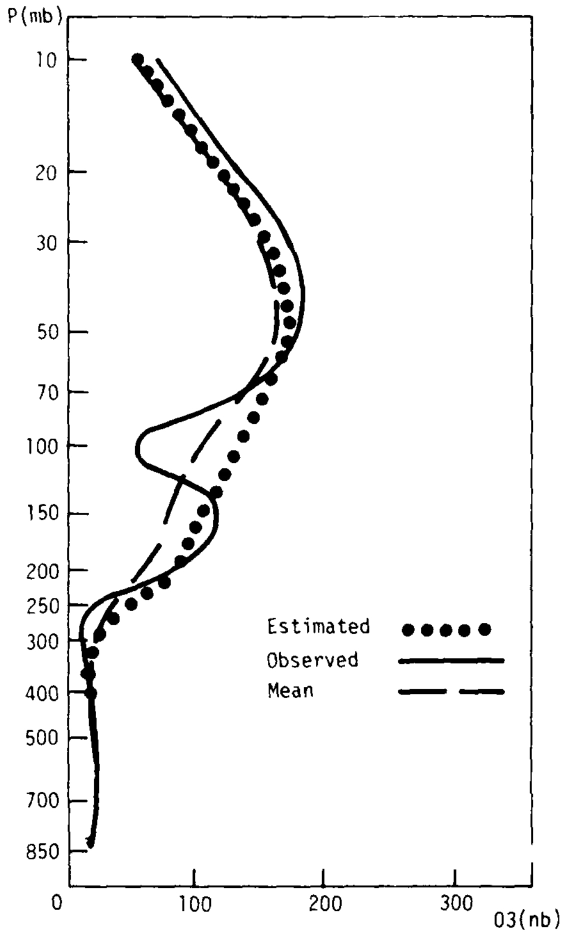

Figure 2. Validated ozone profile. Hohenpeissenberg (48°N. 11OE) 2/23/79 7Z TOMS - 388 M-AIM-CM.

tribution of the ozone in that column.

Figure 3 is the statistical average error of several hundred ozone estimates. If you know nothing more about the ozone field than climatology, the error on a given day, compared with ozonesondes, is shown here in the shaded area which varies from 30 to 60 nb. Now, compare those errors with the errors of our estimates. Figure 4 shows errors only half as large with a maximum of 30 nb.

Now that we can get vertical profiles of ozone, ozone maps can be prepared. Figure 5 is a Northern Hemisphere map of ozone at 100 millibars (about 50,000 ft) showing a deep wide maximum over NE North America and another one over Japan, and two small minima.

Figure 6 gives the height field at 100 mb. The low in the height field is over NE North America and another one is over Japan. The ozone maxima, shaded area from Figure 5, corresponds to the pressure troughs. The ozone minima are found in pressure ridges.

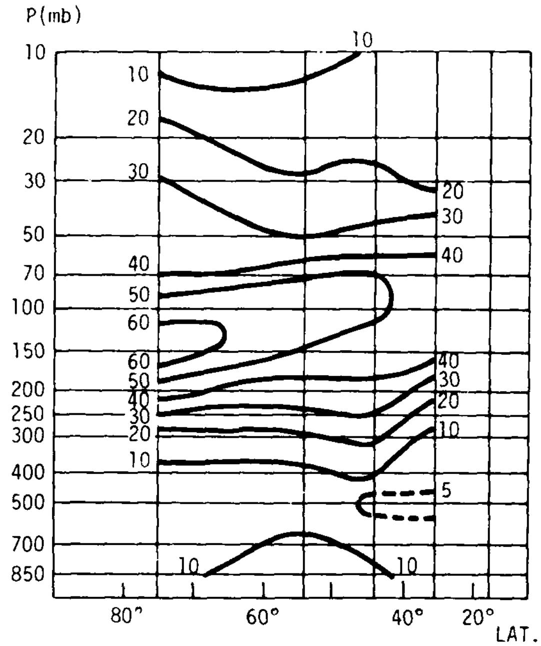

Figure 3. RMS differences between observed ozone and climatology for winter 70-74. (nb)

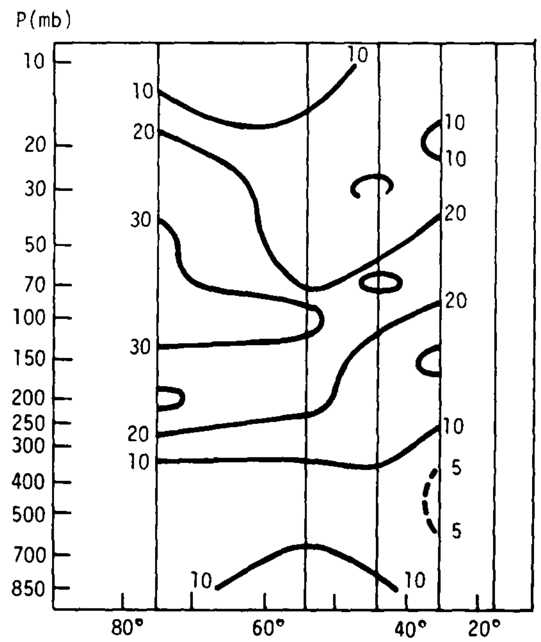

Figure 4. RMS differences between estimated and observed profiles for the mean layer approach. (nb)

That summarizes the error distribution using ozone profiles, but this is closely related to where the tropopause is. I would like to show two figures on what has been done in re-defining the tropopause. Most of the complaints I think on NMC forecasts for aircraft use have been on the height of the tropopause. We've modified the

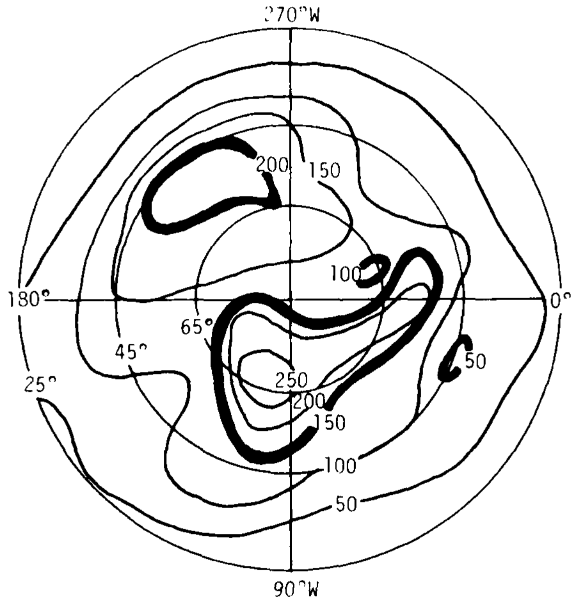

Figure 5. Estimated ozone at 100 MB (nb). 4/1/79 12Z.

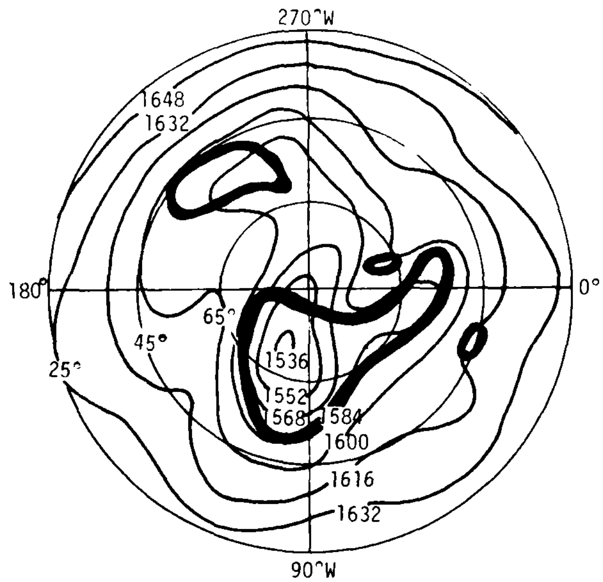

Figure 6. 100 MB Heights (GPM x 10). 4/1/79 12Z.

WMO definition to lower it to agree with where the ozone increases above the tropopause. Thus, our definition could be called the ozone tropopause, and it varies as usual with latitude and season.

There is no time to go through an explanation of how we arrived at our modification. Figure 7 shows an ozonesonde time series based on one ob-

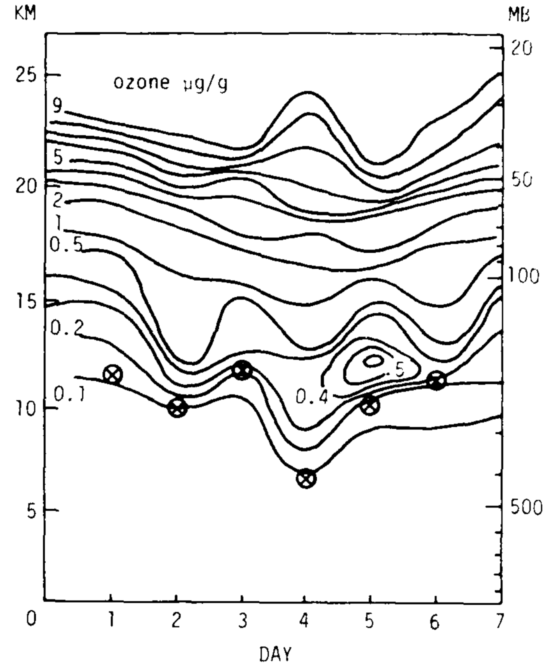

Figure 7. Time section of ozone concentration at Tallahasse, Florida for 13-20 January 1965. Ozone mass mixing ratio is $^{-1}$. Tropopause levels using the WMO definition (given by X's) and the proposed definition (given by O's) are added.

servation per day at a given station. The contours are concentrations of ozone. In the tropopause, ozone is so well mixed one can't draw contours. When you get just above the tropopause or near the tropopause, it starts out near 0.1 microgram per unit, mixing ration unit, then increases to 0.2, 0.3, and up to 0.5, and then it increases very rapidly as you go above that. The crosses show the conventional WMO tropopause height. In this instance, there was a very deep low on the fourth day, and the ozone concentration came down into the troposphere, i.e. what would be called troposphere according to the WMO definition. Our definition, shown by circles, shows the tropopause is lower on the fourth day which agrees with where the ozone starts to increase in the stratosphere.

Figure 8 is a diagram from on of Danielson's papers showing a very detailed case study of a stratospheric outbreak into lower altitudes. The WMO tropopause is shown by the crosses in this case; the circles show where our tropopause would be. The fine dashed lines here are of ozone, so again in this comparison which was made after our work was done, our tropopause agrees fairly well with the ozone concentration. It all boils down to how you define stratosphere, troposphere, and tropopause. We defined our tropopause level at the lowest level at which ozone increases, although that altitude is still computed in terms of temperature. In

other words, we defined the stratosphere as the region of strong concentrations of various trace gases, and using ozone in this case, we feel that the level at which ozone increases is a better indication of where the stratosphere begins rather than a level based on a rather rigid definition from temperature gradients along.

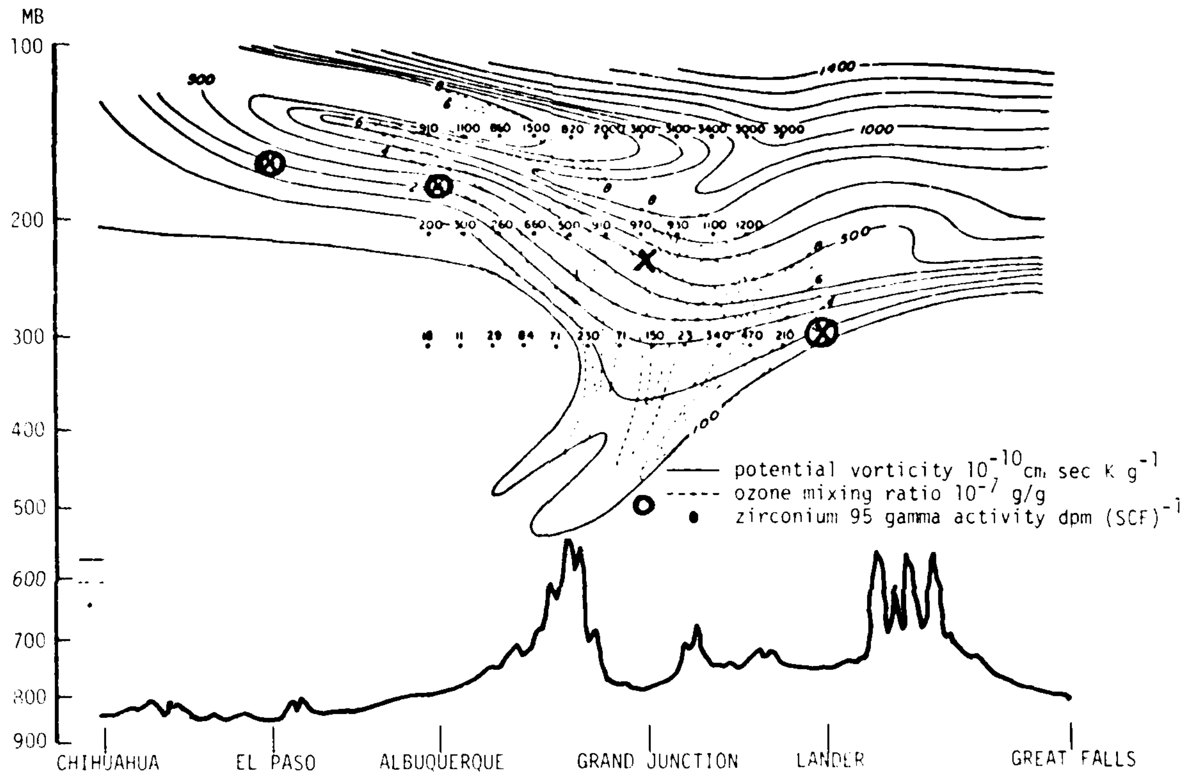

Figure 8. Vertical cross section showing stratospheric extension of potential vorticity (solid lines), ozone (dashed lines), and zirconium 95 activities (plotted numbers) for 12 GMT 25 April 1969. The WMO tropopause has been entered by X's and the proposed tropopause by O's. The topography and location of rawinsonde stations are depicted at the bottom.

*SOURCE: Danielsen et al., J. Geophys. Res., 75, p. 2360, 1979, copyrighted by the American Geophysical Union.